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A Framework for Assessing Safety Culture

Master's thesis in Chemical Engineering, PPUX05

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Summary

The concept of safety culture was first discussed after the Chernobyl accident in 1986 and has been found to contribute to accidents such as Piper Alpha (1988), NASA Columbia (2003) and TEPCO Fukushima (2011). However, it does neither exist a universally accepted definition of safety culture, nor how it should be measured or graded. Based on the hypothesis that "…*whether or not a single individual operates in a safe way depend on if (s)he is allowed, capable and motivated to do so. Further on, it is assumed that the three aspects depend on the safety culture which in turn is affected by society, the organization, the work team and the individual itself, and when all are in harmony, "man-made" accidents will be minimized*", a framework based on Schein's model of culture and Lee's definition of safety culture for assessing safety culture has been developed.

The development process of the framework is based on a thorough literature review of existing models of (safety) culture and how to assess it. From the result of the literature review, definitions of the aspects *Allowed, Capable* and *Motivated* with associated features for the different societal layers to evaluate were obtained. A grading scale connected to the framework was developed based on the work of Dianne Parker et al.

The definitions of the aspects and the grading scale were initially validated through interviews with six individuals working with safety culture regularly. The entire framework was tested by analyzing two incidents, C/S Costa Concordia (2012) and an event at a Swedish chemical process company (2014).

The analysis of the two incidents came to similar conclusions as the official investigation reports and the majority of the interviewees agreed with the definitions of the aspects and characteristics of the grading scale. However, in order to test the hypothesis, the framework need to be applied in long term studies on full scale organizations without being preceded with any accident. To be able to do so, tools such as questionnaires must be developed and more work must be put in the definition of the aspects and grades in order to validate and achieve a general acceptance in industry.

Key words: Safety culture, Culture, Organizational Culture, Safety Climate

Contents

Abbreviations

ASSE	American Society of Safety Engineers
HRO	High Reliability Organization
HSE	Health, Safety and Environment
IB	Investigation Board
ILO	International Labour Organization
LTI	Lost Time Injuries
OD	Overall Description
OSHA	Occupational Safety and Health Administration
OM	Operational Meeting
PSSR	Pre-Startup Safety Review
SA	Situation Awareness
SMS	Safety Management System
TRCF	Total Recordable Case Frequency

1. Introduction

Errors occur at every plant, usually it ends up as a near miss but sometimes as a fatal accident. The causes to these errors vary; poor maintenance, instructions not followed, the personnel not trained enough etc. The following question must then be asked; Why? Obviously someone, operator or manager, did not prioritize the task. This prioritizing is either an active or a passive choice, regardless of which, it is affected by the safety culture that the personnel is working in.

Safety culture was not properly discussed until the late 1980's when the repercussions of the Chernobyl accident in 1986 were analyzed (1). Although lots of research has been made in the area, the Chernobyl accident was not a onetime accident where safety culture was a root cause, for example, both the Piper Alpha accident in 1988 and the Columbia accident in 2003 was in some way caused by decisions made due to absence of a good safety culture (2,3). To avoid future accidents, many organizations and businesses are today working with either improving their safety culture or maintaining it at a high level, example of this is the airline industry, health care and the company Shell whom for several years have worked towards becoming a High Reliability Organization (HRO) (4). A HRO have a very good safety culture and are organizations that are able to manage and sustain almost error-free performance despite operating in hazardous conditions where the consequences of errors could be catastrophic (4).

Changing culture are for several reasons difficult, not only has the old culture to be un-learned, which is considered uncomfortable for many people, the values and believes of the desired culture have to be accepted and understood by the whole organization (1). The first step, before taking any actions, is to evaluate whether or not the safety culture have to be changed and if so, where in the organization changes should be made.

1.1. Hypothesis and aim of the project

The hypothesis is that whether or not a single individual operates in a safe way depend on if (s)he is allowed, capable and motivated to do so. Further on, it is assumed that the three aspects depend on the safety culture which in turn is affected by society, the organization, the work team and the individual itself, and when all are in harmony, "man-made" accidents will be minimized. Finally, it is presumed that it is possible to develop a framework to evaluate the safety culture according to the levels in society and the three aspects mentioned above.

1.1.1. Aim

The aim of the project is to, from the levels; "Society", "Organization", "Work team" and "Individual", and the aspects; *Allowed*, *Capable* and *Motivated* – to operate in a safe way, develop and test a framework with associated grading for assessment of safety culture.

1.2. Limitations

The project is limited to develop the framework for assessing safety culture through defining the aspects, finding suitable indicators and develop a grading scale related to the aspects and the societal levels. No questionnaire or other evaluation tool will be developed during the project. The project will not consider hardware.

2. Theory

Depending on industry and size of production, different amount of protection is required (5). Since production generates the economic conditions that make protection feasible, production tend to be prioritized during the lifetime of an organization (5). Safety requires resources in form of personnel, time and money, and overprotecting is not economically feasible, though, totally neglecting safety entails a high risk of a catastrophe which in the end might result in bankruptcy (5). Relating to figure 1, it is necessary to operate in the white area with a sustainable relationship between production and protection.

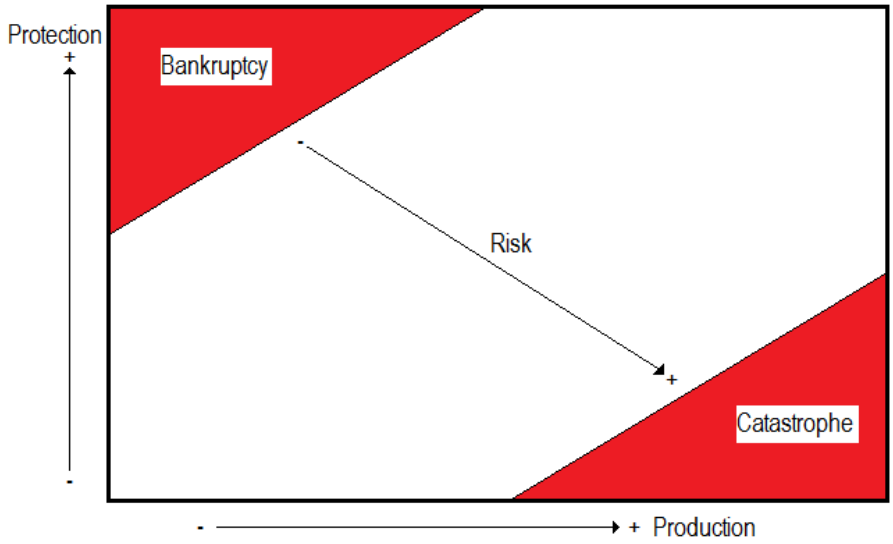

Figure 1, production vs. protection, adapted from Reason (5)

Organizations' approaches to protection have changed over time (6). The first approaches, based on engineering and technology were followed by an approach built on systems for risk assessment, competence requirements and certification. However, both approaches came to a point where safety measures such as Loss Time Injuries (LTI) and Total Recordable Case Frequency (TRCF) reached a plateau where measures, despite increased efforts, were rather constant over time (6). During the second half of the 90's when the plateau for the second approach started to appear, focus was moved towards the human factor, and within that, safety culture (6). Figure 2 visualizes the development of protection approaches over time.

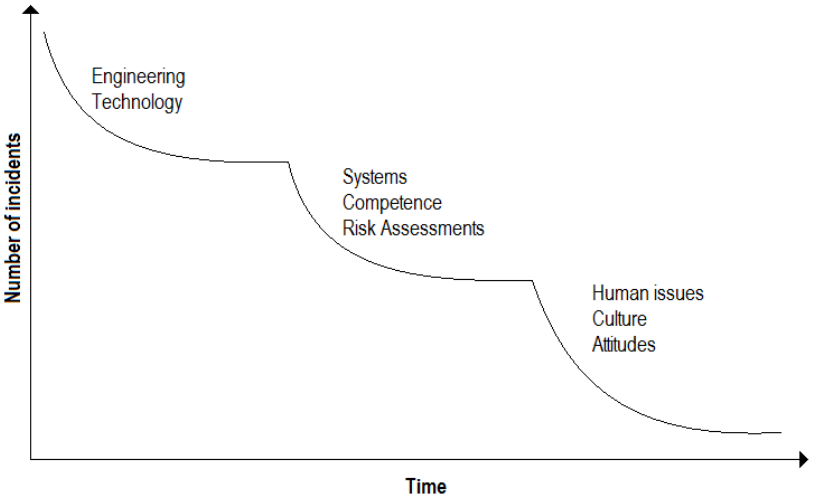

Figure 2, visualizing the incident rates for different approaches to safety over time, adapted from Hudson (6).

2.1. Organizational culture

Safety culture was enlightened after the Chernobyl accident in 1986 (1), and stems from the organizational culture (7). To fully understand the concept of safety culture, it is hence necessary to have an understanding about organizational culture. Although the concept of organizational culture had been discussed for several years, the interest for it increased during the early 1980's (8). There are two approaches towards organizational culture, one stating that culture is something that an organization "is", and one stating that it is something an organization "has" (9). The "is" approach is mainly found in academic groups, the "has" involves the possibility of changing the culture and is favored by managers and management consultants (9).

Even though organizational culture is a widely known concept, there does not exist a universally accepted definition of it. Two definitions of safety culture and its components are developed by Edgar Schein and Hofstede et al.

Edgar Schein has defined organizational culture as; "Organizational culture is the pattern of shared basic assumptions that a given group has invented, discovered, or developed in learning to cope with its problems of external adaptation and internal integration, and that have worked well enough to be considered valid, and, therefore to be taught to new members as the correct way to perceive, think, and feel to those problems" (10);

Schein divides organizational culture in to three levels; Artifacts, Espoused Values and Basic Assumptions (11). Their meaning and how they relate to each other is displayed in figure 3;

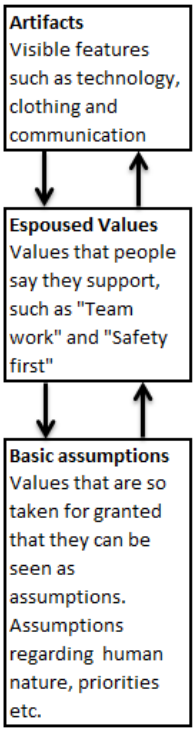

Figure 3. Schein's (12) *three leveled cultural model.*

Hofstede et al. (9) define organizational culture as; "The collective programming of the mind that distinguishes the members of one organization from others". The culture model they have developed is a four level onion, shown in figure 4.

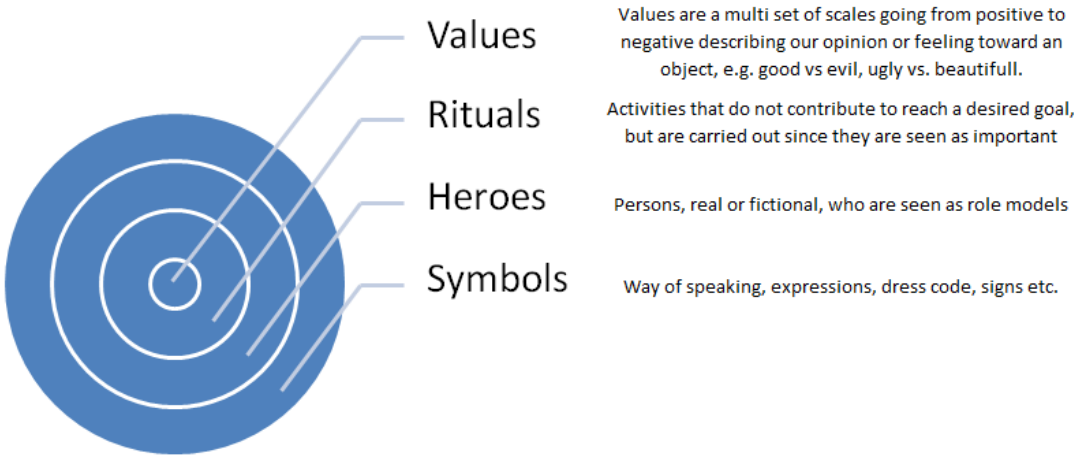

Figure 4, Hofstede et al.'s (13) *four layered cultural model.*

Hofstede et al.'s model is developed for national culture and argues that values are mainly received before we start work and that the organizational culture consists of a combination of Rituals, Heroes and Symbols, which they refer to as "Practices" (9).

Schein's and Hofstede et al.'s models are not the only ones that exist, their and three additional models of culture are presented in table 1.

Table 1, different culture models, adapted from (14)

Reference	**Laye1**	**Layer 2**	**Layer 3**	**Layer 4**

Deal and Kennedy (1982)	Values	Heroes	Rites and rituals	Communication network
Hofstede (1991)	Values	Rituals	Heroes	Symbols
Sanders and Nuijen (1987)	Values and principles	Rituals	Heroes	Symbols
Schein (1992)	Basic assumptions	Espoused values	Artifacts	
Van Hoewijk (1988)	Fixed Convictions	Norms and values	Myth, heroes, symbols, stories	Codes of conduct, rituals, procedures

Although several definitions exist, there are some words that are more frequently used. Verbeke et al. (15) compared 54 definitions of organizational culture, table 2 present adapted data from their report.

Table 2, commonly used words in definition of organizational culture, adapted from Verbeke et al. (15)

Category	**Frequency**
Members	40
Shared	40
Values	30
Organization	28
Behaviour	27
Beliefs	23
Patterns	21
Norms	17
Learned	16
Way	15
Meanings	15
System	12
Assumptions	11

Comparing Schein's and Hofstede et Al.'s model, Schein's contain more of the frequently used words.

2.2. Safety Culture

Although the term safety culture was not introduced until 1986 in the International Atomic Energy Association's (IAEA) accident report of Chernobyl, the concept have been discussed since the early 1980's (8). As for organizational culture, no universal definition exist, Frank Guldenmund (14,16), have summarized some definitions of safety culture. Complemented with the first definition of safety culture developed by IAEA in 1988 (17), an adapted version of Guldenmund's results presented in table 3.

Table 3 Summary of definitions of safety culture, adapted from Guldenmund's data (14,16).

Reference	**Definition**
IAEA (1988)	Safety Culture is that assembly of characteristics and attitudes in organizations and individuals which establishes that, as an overriding priority, nuclear plant safety issues receive the attention warranted by their significance.
Cox and Cox (1991)	Safety cultures reflect the attitudes, beliefs, perceptions, and values that employees share in relation to safety
International Safety Advisory Group (1991)	Safety culture is that assembly of characteristics and attitudes in organizations and individuals

	which establishes that, as an overriding priority, nuclear plant safety issues receive the attention warranted by their significance.
Pidgeon (1991)	The set of beliefs, norms, attitudes, roles, and social and technical practices that are concerned with minimizing the exposure of employees, managers, customers and members of the public to conditions considered dangerous or injurious
Ostrom et Al. (1993)	The concept that the organization's beliefs and attitudes, manifested in actions, policies, and procedures, affect its safety performance
ACSNI (1993)	The safety culture of an organization is the product of individual and group values, attitudes, perceptions, competencies, and patterns of behavior that determine the commitment to, and the style and proficiency of, an organization's health and safety programs. Organizations with a positive safety culture are characterized by communications founded on mutual trust, by shared perceptions of the importance of safety, and by confidence in the efficacy of preventive measure.
Geller (1994)	In a total safety culture (TSC), everyone feels responsible for safety and pursues it on a daily basis.
Berends (1996)	The collective mental programming towards safety of a group of organization members
Lee (1996)	The safety culture of an organization is the product of individual and group values, attitudes, perceptions, competencies, and patterns of behavior that determine the commitment to, and the style and proficiency of, an organization's health and safety management.
Guldenmund 2000	Those aspects of the organizational culture that will impact on attitudes and behavior related to increasing or decreasing risk.
Hale (2000)	The attitudes, beliefs, and perceptions shared by natural groups as defining norms and values, which determine how they act and react in relation to risks and risk control systems.
Richter & Koch (2004)	The shared and learned meanings, experiences, and interpretations of work and safety—expressed partially symbolically—which guide peoples' actions toward risks, accidents, and prevention.
Westrum (2004)	The organization's pattern of response to the problems and opportunities it encounters

Guldenmund (14), concludes that ACSNI's definition include a large amount of what is assumed to be a part of safety culture. The ACSNI definition is also supported by James Reason (8).

Reason's (8) model of safety culture consist of four sub cultures that build up what Reason refers to as an informed culture. An informed culture can be described as; an organization that analyzes gathered information from audits and reports of errors and spreads the information within the organization,

resulting in that managers and operators are aware of the different factors that affect safety. The four subcultures are;

- ***Reporting culture***, people are keen to report their mistakes and near-misses.
- ***Just culture***, characterized by an environment where personnel's mistakes are seen as useful information regarding the safety, though, there are clear guidelines of what behavior is not acceptable.
- ***Flexible culture,*** adapt to an emergency situation and can switch between e.g. a hierarchal structure to a structure where local authorities can make decisions and afterwards return to the original structure.
- ***Learning culture,*** there is a will and capability to analyze the information on the safety system in the organization and take actions when there is need.

Based on the ACSNI model, M.D. Cooper (18) developed a model of safety culture, consisting of three elements, presented in table 4.

Table 4, Cooper's elements of safety culture, adapted from (18)

Element	**Description**
Person	How people feel, attitudes and values
Situation	What the organization has, Safety Management System etc.
Behavior	What people do

3. Assessing safety culture

3.1. Measure

Depending on the definition of (safety) culture and its components, there are different methods for measuring and evaluating safety culture in an organization. Considering Schein's cultural model, there are different methods suggested for measuring the different layers. Starting with "Artifacts", IAEA (1) states that the level should be evaluated by talking to personnel regarding what they reacted to when hired and if the items are still present. It is suggested by several that "Artifacts" can be evaluated by considering visible and audible items (14,19).

There is different opinions regarding how to measure "Espoused values", IAEA (1) promote reviewing of documents such as strategic plans and discussions/interviews with employees. Guldenmund (14) assign "Attitudes" within "Espoused values" and present a large number of studies that to some extent have aimed at evaluating the attitude toward safety related issues by using questionnaires. Schein (12) suggest a combination of Guldenmund's and IAEA's approaches.

Evaluating the "Basic assumptions" is more difficult than the two outer layers (20). Due to that people sometimes are not aware that they possesses them, basic assumptions can be very hard to reveal, Schein (12) suggest a combination of thorough observations, focused interviews and if possible, involving interested group members in self-evaluation when evaluating a groups "Basic assumptions". IAEA (1) and Roughton et al. (20) support Schein's method of observation and interviews but also comment on the importance of comparing the "Espoused values" with the "Artifacts" to find consistencies and inconsistencies that can give a hint of the "Basic assumptions".

Hofstede et al. states that the outer layers in the model, i.e. "Practices", are observable to an outsider but consider it "cumbersome and ambiguous" to interpret values from the way people act and behave, instead, it is suggested that questionnaires should be preferred (21). However, while promoting questionnaires, Hofstede et al. highlights that people's behavior can deviate from their score on the questionnaire and depending the formulation of the question, people might answer how they think that it should be and not how it is (21).

Considering Coopers (18) model, it is stated that the "Person" element should be evaluated by questionnaires, "Situation" by auditing and reviewing the safety management system and "Behavior" by using checklists for safety behavior.

In the recommendations to "Safety Culture Assessment Review Team", IAEA (22), without referring to any certain model, proposes a combination of interviews, observation of behavior, document reviewing and if time is available, a questionnaire when analyzing safety culture.

Finally, there exist a large number of different questionnaires (14) aiming at assessing and measuring safety culture. However, using singly a questionnaire will not cover all levels of safety culture but is more likely to measure the safety climate (23). Safety climate is a part of safety culture, though not as stable but more superficial and inconstant, it can be described as the attitudes and believes at a certain time (24,14). Referring to Schein's cultural model, (safety) climate does not include the basic assumptions (24).

3.2. Grading

In 1992, Ron Westrum developed a three stage grading scale for organizational culture regarding their attitude towards safety-information (25). The scales and parts of their characteristics are presented in table 5.

Table 5, Adapted version of Westrum's (26) *grading of organizational culture.*

Pathological	**Bureaucratic**	**Generative**
Don't want to know	May not find out	Actively seek information
Messengers are shot	Listened to if they arrive	Messengers are trained
Failure is punished or covered up	Organization is just and merciful	Inquiry and redirection
New ideas are actively crushed	New ideas present problems	New ideas are welcomed

Westrum (26) also states that to reach the top level, an organization must have an open mind to find hazards and possible risks in combination with methods of testing the system, by Westrum referred to as "requisite imagination".

The importance of information in a positive safety culture is also discussed by Reason (5). His model of safety culture does not describe different levels or grades of safety culture but instead the features an organization possesses when there are an effective safety culture. Reason states that an organization that has the characteristics of an informed culture, basically has an effective safety culture (5).

Although Reason does not develop a grading system himself, he suggests that Westrum's model should be complemented with two levels, reactive and proactive, between pathological and bureaucratic and bureaucratic and generative respectively (27).

The five level grading scale suggested by Reason was in 2005 further developed by Dianne Parker, Matthew Lawrie and Patrick Hudson (27). From Westrum's descriptions, the five levels were described in the following way (27);

- **Pathological** Who cares about safety as long as we are not caught?
- **Reactive** Safety is important: we do a lot every time we have an accident.
- **Calculative** We have systems in place to manage all hazards.
- **Proactive** We try to anticipate safety problems before they arise.
- **Generative** HSE is how we do business round here.

To describe the different levels in a more detailed way, Parker et al. conducted in-depth interviews with 26 employees at oil and gas companies who had worked their way through the organization to becoming senior executives in their companies. The outcome of the interviews was eighteen aspects with characteristics described for each of the five levels (27).

There are a few models that are developed that do not stems from Westrum's model. In 2001, the Keil Centre in Edinburgh presented a draft for a "Safety Culture Maturity Model" describing five levels that an organization goes through while improving the safety culture (28), presented in table 6.

Table 6, the five leveled scale for safety culture maturity developed by the Keil Centre (28).

Level	**Name**	**Description**
1	Emerging	Safety is seen as technical and procedural issues. Incidents considered a part of the job. Low interest in safety.
2	Managing	Safety can be solved with rules and following procedures. Lagging indicators[1] as safety measurement.
3	Involving	Realize that operators must be involved to improve safety. Management realizes that they sometimes are responsible for accidents. Employees understand their responsibility for health

[1] Lagging indicators are reactive measures and include measures relating to personal injuries and equipment damage (34)

		and safety.
4	Cooperating	General understanding that health and safety is important both ethical and economic. Safety measures are leading indicators[2].
5	Continually improving	There is a common understanding that there are an accident in the near future and the entire organization is working to improve safety performance

Another model not related to Westrum's is IAEA's (1) three stage model, with the following definitions;

- **Stage 1** Safety is based on rules and regulations, mainly focusing on procedures and safety is considered to be a technical rather than human issue.
- **Stage 2** Safety is considered an organizational goal, increased awareness of human issues and there are safety goals with associated responsibilities.
- **Stage 3** Safety can always be improved, the human contribution to safety is fully acknowledged and there is an ongoing process to improve and optimize safety related tasks.

[2]Leading indicators are aiming at measuring variables assumed to be able to indicate safety breaches before an accident occur and hence be prevented (34)

4. Method

The project consists of two main parts, Development and, Validation and Testing.

4.1. Development

The development of the framework consisted of four parts;

- ***Finding a cultural model that is suitable for the questions*** through a literature study of existing models.
- ***Defining aspects*** from the definition of the hypothesis.
- ***Develop a grading scale of safety culture*** through a literature study of existing grading systems and adaption of it to the framework.
- ***Finding indicators, and methods for how to look at them, to evaluate the aspects on each level*** through a study of existing evaluation models in combination of analyses of accident reports.

As support during the development of the framework, five questions regarding safety culture were directed to a panel of experts through an adapted version of the Delphi method.

4.1.1. Delphi method

The Delphi method was developed under the 1950's by a US Air force founded project aiming at using a panel of experts to agree on where Soviet would aim their atomic bombs at (29). There are four aspects required in a Delphi method; anonymity of participants during the process, iteration, controlled feedback and statistical aggregation of group response (29). In this thesis will the anonymity be granted by using anonymous questionnaires, the answers of the questionnaires will be summarized by a moderator and sent out to the participants, enabling them to change or complement their answer, hence the three remaining aspects are fulfilled.

4.1.1.1. Delphi questions

The aim of the inquiry was to give guidance in the development of the framework and give support in the above development parts. Due to the expert panels experience in the field in combination with either inconsistent opinions or poor evaluations in some areas, their opinion in the following questions was sought:

- What is the most effective way to reveal an individual's true opinion (basic assumptions) in a question instead of "how it is supposed to be" / what it thinks is the correct answer?
- What role do non-governmental groups, e.g. unions and post-elementary schools, play when it comes to creating a good safety culture?
- What are the largest pros and cons with measuring safety with "hard values" such as Lost Time Injuries and number of near-misses? In what way do they reflect the safety culture in the organization?
- What is the difference between "Being able" and "Being allowed" to operate in a safe way?
- How is safety culture changed / improved in the best way?

The persons asked to participate were all found to have such a level of knowledge in the area to be considered experts. Further on, to get as a versatile image of the questions as possible, work was put in finding individuals from a variety of industries. The final panel consisted of eight experts with different professional experiences of safety from a variety of industries were consulted.

4.2. Validation and Testing

The scope of the project was presented for six individuals who have professional experience of safety culture. After that interviews were held where their opinion regarding the definitions of the aspects

and adapted grading scale was assessed. Four of the six interviewees were participating in the Delphi assessment and the validation. The two additional interviewees were selected in order to increase the number of represented industries.

Although the framework aims at assessing safety culture at any point of time, the testing of the framework was restricted to evaluating two incidents, the C/S Costa Concordia accident and a near miss at a Swedish chemical process company[3]. The reason for not analyzing an organization is the absence of evaluation tools that have not been developed. The incidents takes place on *Individual/Work Team* and *Work Team/Organization* level respectively and were chosen since they enables to test the framework to a larger extent.

[3] The company want to remain anonymous and will here on be referred to as "The Company"

5. Development

5.1. Aspects

The hypothesis of the project presented in the introduction section states that if being allowed, motivated and capable to operate in a safe way are fulfilled on all societal levels, "man-made" accidents will be minimized. Based on the hypothesis, the definitions of each aspect presented in table 7 were developed.

Table 7, definitions of when aspects are fulfilled.

Allowed	***Capable***	***Motivated***
Clear instructions regarding safety that are updated according to equipment and structure, describing: • Responsibilities • What shall be done • When shall it be done • How shall it be carried out • Who shall do it Responsibilities and work descriptions are understood and accessible	Competence meets required needs, education and training is of high quality and under constant development. Competence is considered important and necessary, positive attitude towards training	Safety is stated to be of high priority and is supported by acts for monitoring, improving and encourage safety. There is a motivation to work and act safe.

5.2. Cultural model

Containing behaviors as well as opinions and values, the definitions of the aspects can be fitted to both Schein's (11) and Hofstede et al.'s (13) cultural model. However, while Schein (12) choose to assign all visible and audible signs in one category (Artifacts), Hofstede et al. (13) divide those over two levels (Rituals and Symbols). In a similar way, Hofstede et Al. have assigned values in one category (Values), while Schein divide it in to two categories, one for the values that individuals are aware of and one for the ones that are so deeply rooted that people often are unaware that they have them (Espoused values and Basic assumptions respectively), meaning that what is seen and hear is not necessary the true culture (14).

History have shown that although "Safety first" might be stated by management, it is not supported in action (among others, BP Texas City refinery accident in 2005 (30)), supporting Schein's difference between stated values (espoused values) and true values (basic assumptions). In combination with the recommendations that exist regarding how to measure Schein's levels and the facilitation of having one layer for artifacts instead of two, Schein's cultural model will be used in the project.

The definition of safety culture that has been found most suitable to the framework is the one suggested by Lee (1996): "*The safety culture of an organization is the product of individual and group values, attitudes, perceptions, competencies, and patterns of behavior that determine the commitment to, and the style and proficiency of, and organization's health and safety management*". Lee's model is considered best since the definition includes the individual and group perspective, and values and patterns of behavior can all be fitted in Schein's cultural model (12). Lee's model also discusses attitudes, commitment and competencies, features reflected in the aspects *Motivated* and *Capable*.

5.3. Grading

In order to adapt an existing grading scale to the structure of the framework, it was considered necessary that the original grading scale had clear guidelines for the different grades that was easy to understand. Further on, the grading scale must be adaptable to Schein's cultural model, resulting in that all grading scales that are associated to questionnaires were ruled out.

Three grading models for safety culture in organizations fulfilling the needs were found;

The "Safety culture maturity model" developed by the Keil Centre, (28) is a five level model describing the different stages an organization goes through when evolving its safety culture. The model was developed through group interviews with people having experience in the field, e.g. safety experts, managers and operators. The levels and descriptions are presented under the theory section in table 5.

However, for the model to be relevant, the following aspects must be fulfilled (28);

- Working safety management system
- The majority of errors are not caused by technical failures
- Health and safety regulations are followed
- The safety work is aiming at preventing errors and not at avoiding charges.

Further on, the model have not been validated (28), which in combination with the restrictions above result in that this model will not be considered further in this project.

IAEA's (1) grading model consists of three stages, presented in table 8.

Table 8, IAEA's three leveled scale for safety culture, adapted from (1)

Stage	**Description**
1	Safety work is aiming at meeting laws and regulations. Negligible effort put into attitude issues, safety is a technical, rule and procedural issue.
2	There are safety goals and targets that go beyond rules and regulations. Growing interest in attitude and behavioral issues, however, safety is still mainly a technical and procedural issue.
3	There is a general perception that safety is important and that it constantly can be improved and enhanced. Safety is no longer a technical and procedural issue but the entire organization are familiar with the safety culture concept.

There is neither any information regarding how the model has been developed, nor if it has been validated in some way and IAEA's model will due to that not be considered further.

The third grading model is the "HSE culture ladder" that stems from Westrum's (26) grading of organizational culture and includes the two levels reactive and proactive suggested by Reason (27). The model was presented under the theory section, a more thorough description of the levels are presented in table 9.

Table 9, the HSE-ladder, data modified from (31)

Level	**Description**
Pathological	Accidents are caused by individuals, who usually are blamed for incidents. All HSE work is based on regulations. "Who cares as long as we're not caught?"
Reactive	Individuals and workforce considered as main problem, difficult to implement safe guards for incidents that have not occurred yet. "Safety is important: we do a lot every time we have an accident"
Calculative	HSE is valued and there are systems in place for e.g. training and procedures. HSE

	metrics are focusing at hard values e.g. number of trained people and not their competence. “We have systems in place to manage all hazards.”
Proactive	General understanding of the importance of HSE, management know that they play a part in accidents, error reports and near misses are used to prevent full size accidents. “We try to anticipate safety problems before they arise.”
Generative	Procedures and equipment are approved by the entire organization. Everyone consider HSE as top priority. “HSE is how we do business around here.”

The “HSE culture ladder” is used by a large number of companies and organizations, among others; Shell (6) and Vattenfall (87).

The different levels in the “HSE culture ladder” were further defined by Parker et al. (27), who through in-depth interviews with 26 executives in the oil and gas industry, reviled, validated and assigned characteristics for eighteen aspects associated with safety culture to all levels, regarding behavior, competence and attitudes. In a study at petrochemical companies in Brazil, Parker et al.’s work was successfully used to develop and describe characteristics for the grades for aspects not included in the original eighteen (32). Although both frameworks were developed for an entire organization, it is considered possible to adapt the grading scale to all the societal levels in the framework. Due to the support the grading scale has in industry and the proved possibility of adapting it to new aspects, the HSE-culture ladder will be used as grading in the framework.

5.3.1. Adapting grading to the aspects

From the eighteen aspects described by Parker et al. and the adapted aspects in the Brazilian study, characteristics for each grade were suggested for every combination of social layer and aspect. Parker et al.’s aspects and its definitions and the adapted grades are presented in appendix A1 and A2 respectively.

6. Evaluation

Although the aspects are defined in general terms, they refer to different features depending on societal level. Following section presents suggestions for features and indicators to evaluate for the different combinations of societal layers and aspects. However, in combination with reviewing the specific features mentioned below, it is assumed that the framework can be used more generally as well, analyzing behavior and then assess why. The evaluation procedure is described in figure 5.

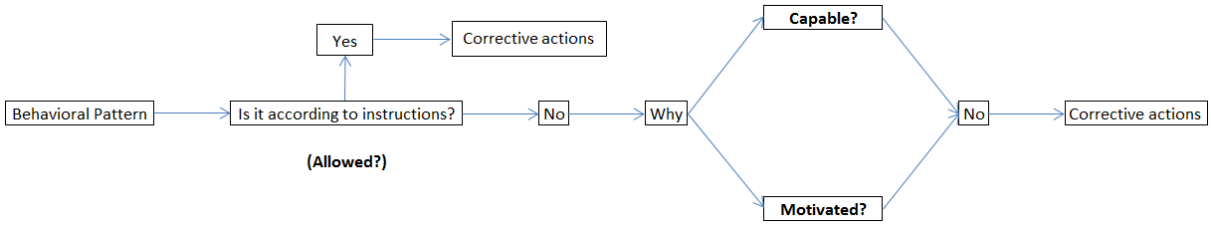

Figure 5, flowchart over general evaluation procedure using the framework.

Further on, as discussed in the theory section, (safety) culture is relatively stable over time, Guldenmund (14) discusses studies stating at least five years. When evaluating the safety culture, it is therefore considered important to not only focus on the current situation but also on how it has been the previous years.

Since the framework aims at being applicable in all organizations, regardless of size and industry, no definitions of the different societal levels will be given. Hence, depending on the size and structure of the organization, different approaches to interpret the data might be suitable. However, referring to Lee's definition of safety culture, it is "*...the product of individual and group values, attitudes, perceptions, competencies, and patterns of behavior...*" it is considered necessary to review the result from the Individual assessment as an average value over a group of people. In case of a large number of Work Teams, it is possible that a similar approach might be used in order to consider the holistic perspective. Though, it is not considered sufficient to review an average value alone, statistical parameter such as standard deviation and variance should be considered in order to assess how representative the mean value is.

6.1. Allowed

Clear instructions regarding safety that are updated according to equipment and structure, describing:

- *Responsibilities*
- *What shall be done*
- *When shall it be done*
- *How it shall be carried out*
- *Who shall do it*

Responsibilities and work descriptions shall be understood and accessible. (Table 7)

6.1.1. Society

Instructions for responsibilities and tasks to be carried out are on the societal level aiming at the formulation of laws and regulations regarding the industry of interest. The evaluation does not include any sort of guidelines as long as they are not explicitly mentioned for compliance with laws. Laws and regulations are here considered as artifacts and can hence be evaluated by reviewing documentation.

Inadequate regulations were found to contribute to both the Esso Longford accident in 1998 and the TEPCO Fukushima accident in 2011. Esso's gas plant in Longford and the industries upstream and downstream were under self-regulatory legislation, requiring identification and control of hazards. However, in difference to the Longford plant, the surrounding industries had to present identified hazards and how they were controlled in a report every five years to regulatory bodies in the state of Victoria. If the regulations would have applied to Esso's Longford plant too, it is likely that hazards contributing to the accident would have been identified (33). The Longford accident enlightens the importance of instructions for how to follow up that laws are complied with.

When evaluating the instructions for following up and controlling that laws and regulations are followed, it is considered important to look at the measures required by regulatory bodies. Safety measures can be divided in to *leading* and *lagging*. Lagging measures are reactive and only suggest actions after an incident or accident has occured, leading measures are active and measures what is believed to be indicators of future accidents or errors (34). Relating this to laws and regulations, it is not only important to consider the type of measurements but also if the regulations are based on how organizations *have operated* in the past or *will operate* in the future.

Although different factors affect the formation of laws and regulations, it is possible to assess if they are updated by comparing them with international standards, e.g. the Seveso directive for industries dealing with hazardous chemicals (35) or IAEA's "Handbook on Nuclear Law". At the time of the Fukushima accident, laws and regulations in Japan were outdated and not according to international standards (36) and the regulatory system were found to be one of the root causes to the accident (37). Required retaliatory measures for severe accidents were, in Japan prior Fukushima, mainly focusing on organizational issues (e.g. human errors) and excluded external events such as earthquakes and tsunamis, despite the fact that these occur frequently in Japan (38).

6.1.2. Organization

Instructions and responsibilities on the organizational level refer to those affecting the entire organization. The documents describing instructions are considered as artifacts and can hence be evaluated by observation (12). Analyzing the knowledge about instructions and responsibilities in the organization require employee surveys, either interviews or questionnaires.

Having clear and understood safety related responsibilities and roles in the entire organization are essential for a safety management system (SMS) (39). SMS is an organization's systematic approach to identify, understand and control risks and hazards through various methods and systems (39). Implementing a SMS have been proved effective, with up to fifty percent less yearly accidents compared to other organizations in the same industry (40). Due to SMS's proven efficiency, it is considered as a good starting point to review available guidelines for content of a SMS when reviewing *Allowed* on organizational level.

There is no universal model for what shall be included in a SMS, however, there are some features that recur, Roughton and Crutchfield (39) states that a basic SMS shall include six features, presented in table 10. Considering more thorough, commercially available guidelines, Roughton and Cruchfield's

content can be found in among other; ASSE's (41), OHSA's (42) and ILO's (43), and is due to that considered as a good basis for analyzing the SMS[4].

Table 10, adapted from Roughton et al. (20).

Feature	**Description**
Management leadership	*Plan for how to make management committed to safety, setting goals and objectives, defining roles and responsibilities for all employees*
Employee involvement	*Plan for how to make employees committed to safety*
Risk and hazard identification and assessment	*System for continuously identifying, reporting, obtaining information regarding risk and how to control hazards and risk*
Hazard prevention and control	*System for continuously reviewing hazards and risks in the work place and tasks, and implement measures to control and remove hazards*
Education and training	*System for assessing training needs, plan for how training shall be conducted and examined*
Performance and measurement	*Measures to assess the status of the SMS, plan for how to review and improve the SMS*

Absence of adequate SMS was one of the causes to the Esso Longford accident in 1998 (44). The reporting system at the time was focusing on incidents related to personal injuries, e.g. lost time injuries (LTI), and not process upsets. This resulted in that an incident, similar to the one causing the explosion, that occurred a month prior the accident was not reported and hence not investigated thoroughly, which could have resulted in avoiding the accident (44).

6.1.3. Work Team

Instructions for procedures and responsibilities on Work Team level refer to the ones that are directly associated with the Work Team. Instructions regarding "Who shall do it" refer to an individual and *Who* that individual is in terms of required competences to take on a task or responsibility. Documents describing instructions and responsibilities are considered as artifacts and evaluation can hence be done by reviewing documents (12).

Poor instructions and absence of well-defined roles with associated responsibilities in a work team have contributed to several accidents over the years. Piper Alpha (2) (1988) and Esso Longford (44) (1998) was caused by inadequate or total absence of instructions, Flixborough (1974), Three Mile Island (1979) and USS Vincennes (1988) are some of the accidents caused by poorly defined and not appropriately demarcated roles (45).

In the Esso Longford accident in 1998, where an explosion was caused by introducing hot oil in a cold heat exchanger, resulting in that the metal cracked and released hydro carbon gas, instructions were neither clear nor updated to the Work Team structure (46,47). The oil had the task of regulating the temperature in the heat exchanger, however, the oil pump went offline for a few hours, resulting in that the temperature dropped from the regular operating temperature of approximately 100°C, down to -48°C. Six years prior the accident, in 1992, all plant engineers was moved from the Longford plant to an office in Melbourne, though, the necessary risk assessment for such change was not conducted, resulting in that expertise regarding temperature constrains of the equipment was absent (47). The operators were left with insufficient instructions that neither described temperature interval where the

[4] As discussed, the elements in table 10 are a basis for assessing the SMS in an organization. For more thorough analysis it is recommended to consider the other SMS guidelines discussed.

heat exchanger could be operated safely, nor the importance of having a continuous flow of oil through the heat exchanger (46).

The process of gathering and interpreting data and use the information to foresee future events called "Situation Awareness" (SA) and can be described as the "mental model" of the current situation (48). The ability of anticipate future events or states is sometimes referred to as "being ahead of the curve" and is important in dynamic industries, e.g. the airline industry where the high speed of planes requires the pilots to know where the plane will be in a near future (48).

SA functions as the initially level in the process of making decisions and failing with any of the levels result in that decisions will be based on a "mental model" that is not corresponding to reality. Such errors have contributed to accidents such as Chernobyl (1986) and Three Mile Island (1979) (48). Shared SA in the Work Team can be accomplished by; sharing relevant information with an understanding how to interpret it, having shift meetings, describing common goals for the Work Team and connections between tasks and employee assignments in the Work Team (49). The absence of sharing relevant information during handovers was found to be contributing causes in both Piper Alpha (1988) (2) and BP Texas City (2005) (50). Besides reviewing how instructions aim at enhanced situation awareness, it is considered important to assess the instructions for how safety shall be communicated in and between Work Teams.

Examining the knowledge about tasks and responsibilities and how to obtain information in case of uncertainties in the Work Team can be made through interviews and questionnaires.

6.1.4. Individual

The instructions for procedures and responsibilities on individual level refer to both the ones affecting individual direct and indirect. Direct refers to the instructions and responsibilities that are related to the assigned role of the individual while indirect refers to general instructions e.g. reporting and how to raise safety inquiries. As for previous levels, documents describing responsibilities and tasks are considered as artifacts and shall be evaluated as such.

The importance of Situation Awareness was enlightened under the Work Team level, however, the concept relates to decision making in general and hence individuals as well (48). Due to the effects absence of SA have resulted in, it is considered important to look at the way instructions contribute to an enhanced SA, e.g. indicators to look at during jobs and how to interpret them, when reviewing instructions for procedures and tasks.

Absence of knowledge of responsibility was a contributing cause at the Texas City accident that occurred during the startup of an ISOM-unit. Prior startups of any unit at the refinery, a Pre-Startup Safety Review (PSSR) was required, including a safety review that considered alarms and equipment as well as training and procedures. The Process Safety Coordinator responsible for the area including the ISOM-unit was not aware of this, resulting in that no PSSR was conducted prior the start up (51).

Assessing the individual's knowledge and acceptance of responsibilities and tasks require the employee to participate in interviews or questionnaires.

6.2. Capable

Competence meets required needs, education and training is of high quality and under constant development. Competence is considered important and necessary, positive attitude towards training. (Table 7)

6.2.1. Society

The required needs on societal level refer to the competence required to meet regulations and the industry's need to operate and develop the business.

Reason (52) states that depending on the level of detail in instruction, different amount of training and competence is required. Relating this to laws, one can compare the highway speed regulations in Germany and Sweden, the German regulations begin with; "Any person driving a vehicle may only drive so fast that the car is under control. Speed must be adapted to the road, traffic, visibility and weather conditions as well as the personal skills and characteristics of the vehicle and load" (53). The Swedish regulations are formulated in a similar way, however, in addition to that, there is a maximum speed limit (54). The Swedish regulation can in this context be seen as more detailed and should, following Reason's statement, require less education compared to the German. Applying this reasoning on regulations of organizations, the required competence to conduct hazard identification and control require higher level of education compared to if clear guidelines for design and operation is provided by regulatory bodies. When assessing if competence available is sufficient to comply with regulations, it is seen as necessary to consult organizations in the industry of interest about their perception. This approach is also considered suitable for assessing the quality of competence, if the competence provided by society meets the organizations requirements to operate and develop the business.

Further on, when assessing the quality of education, there exist several international surveys that rank schools and educations. The surveys assess different aspects and due to the restricted knowledge in that area, no recommendations of lists or surveys to consult will be given in this report.

Assessing the development of education aims at reviewing the process of how schools detect and remove breaches in educations that target the industry of interest. However, schools and other educational institutions have different approaches toward this and it is not seen as feasible to assess all education providers' development process. Instead, evaluating the development of education aims at, through questionnaires and interviews, assessing the involvement of industry, how organizations are consulted in order to detect knowledge breaches, and if there are any noticeable improvements.

Revealing basic assumptions require thorough observations, focused interviews and if possible, self-analysis by interested members of the group (12). However, conducting all of these is not considered possible on societal level due to the large amount of schools, regulatory bodies, unions, individuals etc. that would have to be involved. The same reasoning applies to assessing the espoused values regarding competence, which can be revealed by interviews, questionnaires and reviewing documented statements (12). Due to this, assessing if competence in the industry of interest is considered important will be restricted to analyzing acts by society affecting education and competence, e.g. conducted research and research fundings. Though, without analyzing the espoused values and the basic assumptions it is hard to understand why something is done (11) and hence if it truly is considered important.

6.2.2. Organization

Assessing if competence meets required needs on organizational level aims at evaluating if the competence is sufficient to conduct procedures and take on responsibilities that relate to the entire organization.

Since an organization is constantly evolving, competence development has to be adapted to new hazards and risks (39). The evaluation of quality and development of the education and training system aims at assessing how the training process is designed and implemented. Both the design and the implementation are considered as observable features, and possible to evaluate through review of documents and interviews. Although the way of teaching might vary depending on industry and course content, the training process generally consist of four steps (55);

- *Identification of training needs*
- *Define desired outcome of training.*
- *Development and conduction of training*
- *Evaluation of training*

Implementing a full system for competence and training will make training more relevant and enhance the effectiveness of all levels of the organization (55).

At the Texas City plant, audits conducted prior the accident in 2005 had shown that competence was not sufficient to meet performance expectations (56). An example of the training process is that training not explicitly required by the Occupational Safety and Health Administration (OSHA), was not conducted (56) . This was due to a cost cutting demand from executives in London issued in 1999, six years prior the accident (56). Other cost reducing decisions that affected training was to conduct a large extent of training by computer (56). The computer based training aimed at memorizing facts and not troubleshooting abnormal events which is more beneficial for operators that might face unusual conditions (56). The inadequate training of operators was found as a cause of the accident (57) and assessing how the organization's training and education system takes the four steps mentioned above in to account is seen as important.

Failing with providing necessary training have contributed to accidents such as Texas City (2005) (57) and Esso Longford (1998) (46). Due to this, the four steps in the training system discussed above are considered important to review when assessing the opinion on and attitude to competence on the organizational level.

Evaluating if competence is considered important and assessing the attitude toward training aims at to reveal both the espoused values and the basic assumptions of the organization. The espoused values can be revealed by interviews and questionnaires and the basic assumptions by thorough observations and focused interviews (12). Naturally, the observations and interviews shall be focusing at situations including competence, e.g. the training process. After the Esso Longford accident, it was concluded that competence was missing due to the relocation of engineers and that the training of operators was not sufficient to operate the plant safely (46). The due to this, it is considered important to not only review an organization's work with increasing the competence within the current work force, but also its behavior when people start and quit a job, how competence is reviewed and dealt with when hiring, and during reorganizations and layoffs.

6.2.3. Work Team

Evaluating if competence meets the required needs on Work Team level refer to assessing if the summarized competence is sufficient for the group to carry out assigned tasks. As discussed above, documents is considered as artifacts and can hence be evaluated by comparing training records with the stated competence requirements for the group. By conducting interviews with open ended questions and by using questionnaires it is possible to reveal the espoused values regarding

competence and training (12). However, in order to reveal the true opinion, i.e. the basic assumption, it is necessary to conduct interviews with more focused questions, thoroughly observe behavior and if possible, get motivated Work Team members involved in intensive self-analysis (12).

Obviously, observations and interviews shall be aiming at situations where the presence or absence of competence must be taken in to account. Examples of such situations are found in the Texas City (2005) and Piper Alpha (1988) accidents. At the Texas City plant, operators were assigned task although they did not fulfill the requirements. This applied to the day of the accident as well, and although startups are more hazardous compared to regular refinery procedures (51), the operation was carried out despite the absence of required competence (58). The inadequate training was found to contribute to the accident (50). At Piper Alpha, at the time of the accident, there was a deficit of competent personnel and temporary promotions were made in order to maintain production (2). Both accidents enlighten the importance of assessing the Work Team's behavior when assigning task and when competence is missing.

Other situations discussed in literature are the behavior around training, Parker et al. (27) discusses the extent of which the workforce identify training needs, and Roughton et al. (19) the reluctance by leadership and employees to attend training sessions. While Parker et al.'s discussion is considered more related to the Work Team's contribution to have competence under constant development, Roughton et al.'s focus on the attitude toward competence and training. In association to Roughton et al.'s discussion, it is considered important to assess the group's level of participation during training.

A part from leadership and team structure, a group's performance is affected by its members and their knowledge, skills and personality (59). When evaluating if competence is considered important by the Work Team, assessing how the group reviews and values individual's total competence during a hiring process is considered important.

6.2.4. Individual

On individual level, the required needs refer to the necessary competence in order to carry out assigned tasks and responsibilities and should be assessed by comparing competence requirements stated for the individual, with training records.

Through open ended interviews and questionnaires it is possible to find the espoused values regarding the importance of competence and attitude towards training (12). However, this is not sufficient to reveal the basic assumptions, in order to do that, observations of, and more focused questions about situations with training and competence involved, are required (12). Though, behavior in a group depends not only on the individual's attitude and personality, but also on leadership of the group and group structure (59), interpreting an individual's opinions from his/hers behavior in a group might therefore be misleading. Due to this and despite the risk of not revealing the basic assumptions, interviews and questionnaires are considered as the best solution to assess the individuals' opinion regarding training.

6.3. Motivated

Safety is stated to be of high priority and is supported by acts for monitoring, improving and encourage safety. There is a motivation to work and act safe. (Table 7)

6.3.1. Society

Primary, society on *Motivated* level aims at the regulatory bodies and their statements and acts regarding safety in the industry of interest.

Absence of acts for monitoring and improving safety by regulatory bodies have been found as contributing causes in accidents such as TEPCO Fukushima (2011) and Esso Longford (1998).

Prior the nuclear accident in Fukushima 2011, the regulatory body had instructed TEPCO to conduct anti-seismic backchecks[5]. However, the backchecks were not performed in time by TEPCO and even though the regulatory body was aware of its importance, no actions were taken. The reluctance to take action, both by TEPCO and the regulatory body was found to contribute to the accident (60) and enlighten the importance of reviewing the design and implementation of the reprimand system for organizations that deliver no or poor measures.

As discussed under *Allowed – Society*, the laws affecting Esso's gas plant in Longford and TEPCO's nuclear plant in Fukushima were insufficient. However, prior the accident in Longford, the regulatory body had been recommended by the federal government to include plants such as Esso's gas plant in the same legislation that applied to the industries up-and down-stream from the Longford plant. If such changes would have been made, the accident could have been avoided (44). Japan's regulatory bodies in nuclear were found reluctant to adopt knowledge and technical improvements that were not domestic. As an example it was concluded that if Japanese regulations would have been adapted to American legislative updates that followed the 9/11 attacks and applied those to nuclear facilities, it is possible that the accident in Fukushima could have been avoided (37). As mentioned, the reluctance to update and improve laws and regulations contributed to the accidents, and it is due to this considered important to review the regulatory bodies approach toward updating laws and regulations, if it is reactive or proactive.

An example of a proactive act made to enhance and improve safety was the Swedish governments removal of law 1984:3 6§ in 2006, that prohibited anyone to prepare for construction of a nuclear facility (61). Although the law did not concern research and development within nuclear science, it was concluded that the law affected this area in a negative way. To increase research in the area of nuclear safety and nuclear waste, it was recommended to remove the law (61).

Assessing if there is a motivation to work and act safe by regulatory bodies aim at revealing the basic assumption regarding safety, however, for the same reasons discussed under *Capable – Society*, this is not considered feasible. Evaluating *Motivated – Society* therefore primarily aims at assessing the statements and supportive acts.

Although *Motivation – Society* primarily aim at regulatory bodies, however, it is considered important to mention the non-regulatory part of society and their attitude to the industry. This is due to the direct and indirect effect non regulatory bodies have on companies, e.g. by influencing regulatory bodies or boycott products.

6.3.2. Organization

Statements regarding the importance of safety are espoused values and can hence be evaluated by interviews, questionnaires and reviewing documented values (12). Behavioral patterns are considered as an artefact (11) and the supportive acts can hence be evaluated by observation. Although all acts

[5] Backcheck - A review of the safety of a nuclear power plant

contributing to an enhanced safety are seen as important to review, there are some features that have been proved effective and hence considered important to assess.

Managers' behavior around safety has a large impact on the safety performance in an organization (62). Visible commitment to safety by senior management and middle managers involvement in safety work are examples of acts that enhance the safety performance (62). Middle managers ability to create an open atmosphere with good communication while simultaneously make sure that safety instructions are followed, are other features that have been shown to have an positive impact on the safety in the organization (62).

In order to accomplish an effective safety culture, Reason (8) states that it is necessary to have a *reporting culture* where employees are keen on reporting errors and near misses. The *reporting culture* in turn requires a *just culture* where employees, without fear of being blamed, but rather are cheered and sometimes even rewarded for reporting safety information (8). Beside fear of punishment for oneself or the group, Reason (8) discusses the perception of that the report are to no good can result in that employees consider it not worth the extra work to report errors. At BP's Texas City refinery, employees were not encouraged to file reports and some individuals feared to be punished if doing so (63). Further on, the design of the safety reward system was remunerating employees with low amount of accidents and not the ones operating in a safe way, which might have contributed lower the motivation to report (64). Due to the absence of reports, near misses and errors were not addressed in a proper way. Reviewing management's work to achieve an environment where employees are willing and motivated to report is considered important to assess as acts to enhance safety.

As discussed under *Allowed – Organization*, the poorly designed reporting system at the Esso Longford plant contributed to the accident. At BP's Texas City refinery however, there was a reporting system in place with several safety measures taken, both leading and lagging (64). Though, the measures that were acted upon were the ones relating to personal injuries, e.g. LTI. The fact that the lagging hard measures had a decreasing trend was interpreted as a sign of good safety. The fact that an external audit pointed out several breaches and concluded that; "There is an exceptional degree of fear of catastrophic incidents at Texas City", did not change the perception of an increased safety at the site (65). Management's behavior at Texas City enlightens the importance of reviewing not only which measures that are taken but also which measures that are given attention and acted upon.

Proceeding with BP's Texas City refinery, it was after the accident concluded that the organization had a poor *learning culture* (66). An organization with a *learning culture* is motivated and capable to interpret data from safety information and execute changes if needed (8). When discussing *learning culture*, Reason limits data analysis to the organization's safety information system (8). However, in their eighteen aspects Parker et al. (27) assigns different organizational approaches of benchmarking. In combination with evaluating which organizational measures that are acted upon, assessing how competence is obtained from the organization and other businesses and industries (e.g. by benchmarking) is found vital to evaluate.

A few months prior the accident at Texas City, an external audit concluded that production and meeting budget was rewarded and encouraged before everything else and that safety was compromised for production (65). The same audit found that the main causes for accidents at Texas City to that point had been production and time pressure associated with understaffing (65). Relating this to the framework, assessing if there are situations where it is acceptable in the eyes of management to deviate from safety instructions is important when evaluating the organizations motivation.

Assessing if there is a motivation to act and work safe aims at revealing the basic assumptions within the organization. As discussed under *Capable – Organization*, basic assumptions require thorough observations and focused interviews. The situations and behaviors that the observations and interviews should be aiming at safety related situations, which to a large extent are considered to be the same as the acts to support statements.

6.3.3. Work Team

As discussed under organization, statements regarding safety are considered as espoused values and can be assessed by questionnaires, interviews and reviewing documentation associated with the Work Team (12). Being observable features, the supportive acts can be evaluated as artifacts, i.e. by observations (12). Evaluating if there is motivation to work and act safe aims at assessing the basic assumptions within the Work Team and hence thorough observations, focused interviews and if possible, self-assessments with interested Work Team members are required (12).

Although considering all acts that contribute to an enhanced safety in the Work Team, there are some features that have been proven very effective. As for the organizational level, leadership has a vital role in creating a joint motivation to operate safe (62). Leadership's and supervisors' ability to monitoring and reinforcing workers' behavior, being supportive and encourage safety initiatives in combination with participating in safety procedures and acting as an example enhances the motivation to work safe in a group (62). Further on, the way supervisors and leaders communicate safety with the work force is strongly related to the motivation to work safe in the workforce (67). In a study conducted in 1999 Hofmann and Morgeson (68) showed that employees having good communication, both in general and directly related to safety with their leader showed greater motivation to act and work safe.

Management also have an important role when it comes to create an open atmosphere, in a study from 2003, Edmondson (69) shows that implementation of practices is facilitated by having an atmosphere where it is easy to speak up. Absence of such environment in the airline industry has resulted in that co-pilots have been unwilling to challenge the captain's decision, and have contributed to causing accidents (59). There are different reasons for why people do not speak up two examples are uncertainty if one's information is needed (69) or fear of losing one's cohesion in a group by questioning a respected leader (59). Both reasons negatively affect the decision making in the Work Team (59) and assessing both the acceptance of questioning decision and behavior in the group and leadership's work to accomplish an open atmosphere is considered important to evaluate.

Associated with the importance of an open atmosphere in decision making is the acceptance of information by subordinates (59), an example of when such information was ignored is the Piper Alpha accident in 1988. One factor contributing to the disaster was that the two platforms (Tartan and Claymore) that were connected to the same pipeline grid as Piper Alpha, maintained production when Piper Alpha had caught fire, resulting in that oil was feed to the fire. Although the manager at Claymore, with the authority to shut down production, was warned by operators several times that maintaining production might result in worsen the fire on Piper Alpha, no actions were taken (70).

Continuing on the Piper Alpha accident, it was concluded after the accident that there was a general acceptance of shortcuts and not following procedures and instructions (2). Similar behavior was found at BP's Texas City refinery, where the risk acceptance was remarkably higher compared to similar facilities (71). In difference to Piper Alpha and Texas City, successfully monitoring and self-correcting the group's work enhances the Work Team's performance (59). Assessing the group's

ability to do so, e.g. its behavior in situations when safety restrictions/instructions are not followed, is considered important when reviewing the Work Team's motivation to work safe.

6.3.4. Individual

Statements regarding safety is considered to be espoused values and can hence be evaluated by questionnaires and open ended interviews (12). Fulfilling *Motivated* requires acts that support the statements, however, as discussed under *Capable*, behavior in a group is affected by several factors such as leadership and structure of the group, resulting in that the individual's acts might not be according to his/hers motivation but rather the groups (59). Due to this, evaluating *Motivated* on individual will primarily be assessed through focused interviews and questionnaires.

Evaluating if there is motivation to improve and encourage safety requires evaluating the individual's opinion about the current safety procedures/system and if it is considered to have deficiencies.

Assessing if the individual has motivation to work and act safe, it is considered necessary to evaluate the individual's perception of safe work. As an example, Neal and Griffin (2006) (72) have, from the work of Borman and Motowidlo, divided safe behavior in two categories; compliance and participation. Compliance refers to performing the tasks or undertakings set up to preserve a safe workplace, e.g. personal protection equipment (PPE) or following work procedures. Participative acts or behavior is not directly affecting the personal safety of the individual but contribute to an environment that support and enhanced safety, e.g. voluntary safety activities and facilitating and helping co-workers in safety work.

Indifferent of the interpretation of safe work, it is considered important to evaluate the individual's motivation to work according to instructions and if there are occasions where it is okay to not comply with the system.

7. Testing

The testing of the framework will focus on two events, the C/S Costa Concordia accident in 2012 and a near miss at a large Swedish chemical process company (here on The Company) in 2014. The events have been chosen due to the difference in societal levels involved. C/S Costa Concordia focuses on Work Team and Individual level, and the near miss at The Company on Organization and Work Team level.

7.1. C/S Costa Concordia

All data presented here on is obtained from the investigation report (73) unless other stated. The description of the event, taken from the investigation report (73), is presented in appendix A5.

The analysis of the accident focuses on the events on the bridge before the collision.

7.1.1. Work Team analysis

The personnel on duty on the bridge, during and prior the accident was; 1st deck officer (in charge), 2nd deck officer, 3rd deck officer, an appropriate, a seaman, the helmsman and the master, these will be referred to as the Work Team. Present on the bridge at the same time was also the chief purser, the metre and the catering service manager, who due to absence of official responsibilities are excluded from the Work Team.

7.1.1.1. Allowed

Reviewing the investigation report, the instructions and responsibilities seems detailed and updated according to equipment and group structure, however, several violations of instructions have been found.

Prior the arrival of the master, the chief purser, the metre and the catering service manager were present on the bridge. Non-involved personnel and passengers were not allowed on the bridge unless in specific cases for which the master's explicit approval was required. There are no records of such approval in the investigation report.

Further on, it was stated that "*…banned the use of mobile phones and the private cell phone on board, during the watch, as well as maneuvering"* (73), which was ignored when the master made his call on the bridge.

When the master took command of the watch, handover was not conducted according to instructions and when deviating from the planned route, procedures were not followed. When planning a route, the officer in charge shall consider features such as meteorological, permanent or temporary hazards and always ensure a significant distance to shore. A detailed plan shall thereafter be presented and approved by the master of the ship, no evidence of such procedure was recorded. Finally, in the instructions it is stated that "*…the round consists of the second mate and helmsman without prejudice to the right of the master of the ship to implement the guard for the safety of navigation and environmental protection"* (73). The master had hence no right to take command during the current circumstances.

As discussed above, the instructions and responsibilities seem well defined and up to date, however, there are no information regarding the knowledge about the procedures. With the information available and not considering the knowledge about instructions, the grade Calculative is considered appropriate "*There are instructions regarding, procedures and responsibilities that… …are up to date and adapted to the current group structure and equipment*".

7.1.1.2. Capable

The Work Team's competence is not presented in detail, however, it is concluded in the investigation report that "*First of all, analyzing the background of the crewmembers (Officers mainly) involved in all the different phases of the event (even before the contact), this IB excludes that the casualty and the consequent handling of the emergency is due, in terms of human performance, to the lack of competency*" (73). It is therefore assumed that the Work Team on Capable reached at least the Calculative grade "*The competence in the group meets the required needs to perform the group's tasks*", however it is possible that higher grades are appropriate.

7.1.1.3. Motivated

Considering the fact that non-involved personnel was present on the bridge prior the arrival of the master, in combination with the reluctance to comment or questioning the behavior indicates an acceptance of rule breaking in the Work Team. Only reviewing the investigation report result in that it is not possible to understand why the Work Team behaved the way that they did. Though, the reluctance to questioning the masters behavior result in that the group would not reach a grade above Calculative on Motivation "*…questions regarding safety are not necessary to discuss in group*". However, the absence of handover when the master took over the watch and the acceptance of not following safety regulations even when time was available is more consistent with the definition of Reactive "*Safety information is not or poorly communicated in the group.","… the general attitude is that one should act as told and not ask questions. Safety procedures might be followed in case of time*". This is supported by the investigation report where it is stated that "*…1st Deck officer…before the arrival of the Master had strongly criticized the bridge the decision to follow a route so close to the shore, calling it a true madness.*"

7.1.2. Individual analysis

As for the Work Team level, several gaps exist in order to be able to do a thorough analysis of the individual level. However, the master's behavior is rather well described in the investigation report and will be used as a base for the analysis.

7.1.2.1. Allowed

All of the instructions discussed under *Allowed – Work Team* applies direct or indirect to the master. As discussed above, without interviews it is not possible to say if the instructions were known to or accepted by the master or not. Judging from the investigation report, the instructions for the master seems rather well defined and consistent with the Calculative grade *"Instructions, procedures and responsibilities are well defined, updated… … describing his/hers tasks... There is a clear framework for safety…".*

7.1.2.2. Capable

The reasoning regarding competence under Work Team is applied here as well, i.e. that since the report did not consider absence of knowledge as a root cause, it is assumed that the master's competence is at least sufficient to meet the Calculative grade "*Competence meet the stated needs to perform tasks…*". The master's decision to assess the safe distance to the Giglio island by a call to shore and not by using navigational charts or the competence on the bridge is consistent with the Calculative grade "*When missing competence it is not necessary to consult books or experts but asking a colleague is sufficient, if no answers are found task are carried out any way*".

7.1.2.3. Motivated

The investigation report discusses no statements made by the master, and without interviews it is not feasible to reveal his motivation to work and act safe. Due to that, evaluating the master's motivation to work and act safe aims at his "supportive acts". The master's reluctance to follow instructions and comment on other breaches, such as the presence of non-involved personnel on the bridge is found consistent with the Reactive grade "*Procedures are too cumbersome and not necessary to follow unless audited…*". However, the investigation report do not present that the route deviation would have had any positive outcome, why the Pathological grade is found more appropriate "*There is a feeling that safety procedures are to no good, they are time consuming and unnecessary*".

7.2. Near miss at The Company

The description of the event, taken from the investigation report, is presented in appendix A6. The event description is complemented with an interview with a person with good insight in the event.

7.2.1. Organizational analysis

7.2.1.1. Allowed

Considering the decision to cover the pressure monitors, the investigation report states that it is the correct instances that have made the decision. Further on, it was under the interview stated that the decisions were made according to the defined decision path including risk and hazard review.

While the decision to use shrink tubing was based upon non-updated instructions, the decision was taken by the correct instances. From the complementary interview it appears that the request was made orally by the installers to the experts and since it was not considered to be a safety related issue, no risk assessment was made and hence the shrink tube's affection not detected.

The fact that both the decisions was made by correct instances is interpreted as that the responsibilities were well known through the organization and both Calculative "*The safety management system is adapted to the current structure of the organization and responsibilities are known by ones directly affected by it, in case of uncertainties, it is easy to obtain the required information*", and Proactive "*Responsibilities and instructions in the safety management system are detailed and adapted to the current organization and understood by through the organization*" is considered as suitable grades.

However, as described in the event description, absence of clear instructions resulted in that the introduction of shrink tube was not documented and included in the installation instructions which hampered the troubleshooting. The event report does not clarify if the usage of shrink tubing should have been documented, however, it is stated that "*…is due to the installation company's manager's absence of clear instructions for how such updates shall be conducted".* It seems like there is an uncertainty regarding which hardware changes that shall be reviewed, documented and reported, resulting in that Calculative is considered the most suitable grade.

Further on, the corrective actions taken by The Company are considered to reflect a static "checklist mentality", consistent with the definition of the Calculative grade. The overall conclusion is therefore that Calculative is the most suitable grade for *Allowed – Organization.*

7.2.1.2. Capable

The investigation report does not discuss The Company's training program or behavior around training and competence. However, during the complementary interview it was concluded that Calculative should be the most suitable grade "*Training needs are mainly identified by competence matrices and time since last training sessions, training is standard courses associated to the*

competence matrix. Competence is tested with oral or written examination and practically when suitable. Training is evaluated through questionnaires regarding way of teaching, no evaluation of content or changed habits."

7.2.1.3. Motivated

The Company's behavior around the ground faults is considered to be consistent with the description of the Calculative grade "*…safety work is static and there is little effort in improving safety*". This is based on The Company's behavior during and after the event. To begin with, judging from the event description, the conclusions from meetings are aiming at finding the direct technical causes and remove it in order to restart production. Further on, the corrective actions taken when the cause to the ground fault was detected were to resolve the direct technical issue and update the instructions related to the pressure monitors. Reviewing the actions that were taken after the incident preceding the ground faults, caused by poor instructions, it seems like The Company have a rather poor learning culture. The fact that poor instructions within one year have caused incidents is not used as an indicator of that more instructions might be insufficient, i.e. using the near misses as leading indicators. This behavior supports the Calculative grade with the definition "*There are lots of safety measures taken, the ones given most attention are still lagging hard measures".*

It might be discussed that the corrective actions would be consistent with the Reactive grade "*After accidents or shutdown of the plant it is priority to start production instead of finding the causes for shutdown*". However, the nature of this event is not considered to be of such magnitude that "accident" is an appropriate definition, resulting in that Reactive is not considered suitable.

7.2.2. Work Team analysis

7.2.2.1. Allowed

There were several Work Teams with associated instructions involved in the event. Reviewing the event description and the complementary interview, it is found that Reactive is the most suitable grade. Starting with the decision to cover the pressure monitor containers with isolation was according to the event description based on incomplete blueprints and/or insufficient isolation instructions that did not describe the pressure monitors as sensitive equipment. The fact that there was no specific temperature limitation documented for the pressure monitors and that they were not included in the list of sensitive equipment result in that Reactive is considered to be the most suitable grade, "*The instructions are un-detailed, not updated to current group structure and/or equipment used*". Further on, it is described in the event description that the decision of using shrink tube was made without instructions updated to the new operating temperature in the pressure monitors. The Reactive grade is further supported by the instructions involved in the installation audit. In the event description, it appears that they are rather undetailed, exemplified with the two contradicting sentences "*…the installation manager can determine if a simpler deviation can be corrected without documenting it*" and "*Smaller deviations shall be marked in the installer's modification description*".

It must be commented that a large extent of the instructions were up to date according to equipment and group structure. E.g. considering the instructions for the "testing group", the complementary interview reveals that it was stated that they should conduct megging. The instructions were up to date and although the instructions were not at hand, they were accessible. The reason why the instructions was not retrieved were that megging "usually" was not conducted on this sort of equipment. The instructions are considered consistent with the Calculative grade "*There are instructions regarding task, procedures and responsibilities that are known by the majority of the group and incase of uncertainties the information is accessible, are up to date and adapted to the current group structure*

and equipment". However, the breaches discussed in the previous section are considered to be of such nature that Reactive is the most suitable grade.

7.2.2.2. Capable

From the complementary interview, it is stated that the competence in the Work Teams were meeting the stated needs and that the Calculative grade best describes the competence situation "*The competence in the group meets the required needs to perform the group's tasks. When tasks are assigned, competence is reviewed*".

While Calculative is considered most suitable on the overall review, it must be commented that the installation group's behavior around the usage of shrink tubing is rather consistent with the definition of Proactive "*If competence is missing, it is reported and the task is not performed until new instructions have arrived*".

7.2.2.3. Motivated

Starting with the "testing group" that did not conduct the megging, the Work Team did not retrieve the instructions due to that megging "usually" was not conducted on such equipment. The behavior of the Work Team is found consistent with characteristics for both Reactive "*Safety procedures might be followed in case of time*" and Calculative "*…safety is important when time is available…*". It is from the complementary interview revealed that the Work Team was under time pressure, however not to that extent that it was the underlying cause to why megging was ignored. When the instructions was not at hand, it was, in order to be productive, decided to carry out the other tasks since megging "usually" was not conducted on such equipment. The way of acting is considered similar to the characteristic described for Calculative "*…make "exemptions" if it lead to maintaining production or speeding up startups when time is short*".

From the complementary interview it appears to be a rather open atmosphere during the meetings discussing causes and ways to control the ground fault. It seems like the behavior from management is beyond the definition of Calculative "*There is no active work by leadership to find uncertainties or creating an environment where questions are welcome*", which would imply Proactive to be a suitable grade.

Relating to the indicators discussed in the thesis, it is not considered feasible to draw a conclusion around management's and leadership's presence, behavior and way of communication from the information provided in the interview and event description. Judging from the event description, it is assumed that leaders and managers required were present during meetings and that the Work Teams communicated safety related information as instructed. Due to this and the discussion above, Calculative is found to be as suitable grade for *Motivation – Work Team.*

8. Result

8.1. Answers from Delphi assessment

Following section present a summary of the answers from the Delphi questions. The participants have answered with their own words and have on some questions discussed several features in their answer, resulting in that the sum of answers might exceed the number of participants. In order to visualize the results, key words or phrases have been found and presented with the frequency of which they recur.

Question 1. What is the most effective way to reveal an individual's true opinion (basic assumptions) in a question instead of "how it is supposed to be" / what it thinks is the correct answer?

All answers by the participants included at least one of the following; questionnaires (Q), interviews (I) and/or observations (O). The answers and their frequency are presented in table 12.

Table 12, answers and their frequency on question 1.

Method	***Frequency***
Q I O	3
Q I[6]	1
I	4

Four of the respondents enlighten the importance of an open atmosphere when conducting the interviews.

Question 2. What role do non-governmental groups, e.g. unions and post-elementary schools, play when it comes to creating a good safety culture?

The answers and their frequency from question two are presented in table 13.

Table 13, answers and their frequency to question 2.

Role	***Frequency***
Schools role is to provide competence and knowledge about safety	4
Cooperation and support from unions are very important	3
Small role compared to the organization[7]	3
Industry associations play an important role	1
Positive role	1
Unions and schools have to adapt their talk regarding culture to the organizations culture	1

Question 3. What are the largest pros and cons with measuring safety with "hard values" such as Lost Time Injuries and number of near-misses? In what way do they reflect the safety culture in the organization?

All participants are represented in table 14, presenting advantages mentioned, and table 15, presenting disadvantages mentioned.

Table 14, pros discussed and their frequency in answers on question 3.

Advantages	***Frequency***

[6] In absence of an open atmosphere, anonymous surveys/questionnaires can be used.

[7] While stating that the organization produces its culture, it was discussed that a national culture differing a lot from the organizational might be confusing.

Good for benchmarking and/or trend analysis	4
Measured issues get attention	2
Easy to measure	1
Puts focus on reporting	1
Good for visualization of safety	1
Good in combination with management attention	1

Table 15, cons discussed and their frequency in answers on question 3.

Disadvantages	***Frequency***
Suffer from/might result in underreporting	5
Not a measure of safety culture alone	3
Measures are lagging/reactive	1

Question 4. What is the difference between "Being able" and "Being allowed" to operate in a safe way?

The definitions of "Being able" and "Being allowed" mentioned are presented in table 16 and table 17 respectively.

Table 16, characteristics defining "Being able" and their frequency discussed in answers to question 4.

Definition	***Frquency***
Having pre-requisites	4
Having a Choice	2
Knowledge	1
Understanding of roles and responsibilities	1

Table 17, characteristics defining "Being allowed" and their frequency discussed in answers to question 4.

Definition	***Frequency***
Having permission	3
Having a choice to act	1
Having pre-requisites	1
The "desired way of acting"	1
Clear rules	1

One answer stated that the different is very small and that it is a question about being asked to, and have the motivation to work safe.

Question 5. How is safety culture changed / improved in the best way?

The methods for changing/improving safety culture mentioned in the answers by the participants are presented in table 18.

Table 18, methods for changing safety culture discussed and their frequency in answers to question 5.

Method	***Frequency***
Management commitment	6
Communication and/or safety meetings	3
Training	3
Involving everyone in the safety work	3
By considering all parts of a system at the same time and working with all the aspects	1

(risk control, attitudes and behavior)	
Implementing a comprehensive safety management system	1
Feedback and reporting	1
Appointing safety officers	1

8.2. Validation

The definitions of the aspects and the grades were presented along with the scope of the project for six individuals. The individuals work with safety culture to some extent and represented the nuclear industry, petrochemical industry, surface chemistry industry or academia. The individuals were interviewed face to face or over phone, asked;

1. If the aspects "Allowed", "Capable" and "Motivated" are fulfilled on all societal levels, the risk for "man-made accidents" are minimal?
2. Do you find the grades adapted to the framework consistent with your perception of the HSE-ladder and the definitions of "Allowed", "Capable" and "Motivated"?

The formulations of the answers varied, due to this, the answers have been divided in to positive and negative instead of Yes and No. The result of the interviews is presented in table 19, conditions and comments are presented in appendix A3.

Table 19, result of the interviews.

Question	***Positive***	***Negative***
1	5	1
2	6	0

8.3. Testing

8.3.1. C/S Costa Concordia

Framework

The result of the analysis of the C/S Costa Concordia accident is presented in table 20.

Table 20, result of the analysis of the C/S Costa Concordia accident.

	Allowed	***Capable***	***Motivated***
Work Team	Calculative	Calculative	Reactive
Individual	Calculative	Calculative	Pathological

Investigation report

The investigation board came to the conclusion that the root cause to the C/S Costa Concordia accident was the human factor. It is stated in the report that the accident "*depended only by the above mentioned human element, which shows poor proficiency by key crewmembers*" (73).

8.3.2. The Company

Framework

The result of the analysis of the C/S Costa Concordia accident is presented in table 21.

Table 21, result of the analysis of the near miss at The Company.

	Allowed	***Capable***	***Motivated***
Organization	Calculative	Calculative	Calculative
Work Team	Reactive	Calculative	Calculative

Investigation report

The investigation board states the following ground causes to the incident;

- The Company's resources for isolation responsibility are currently strained, resulting in that the isolation work cannot be conducted in the desired systematic way.
- Several pressure monitors had a sharp edge, resulting in that the shrink tubing was required.
- Breaches in risk identification, communication and understanding of coworker's tasks and assignments resulted in that shrinking tube not certified for the current environment was used.

Following are by the investigation board considered as contributing causes;

- Breaches in instructions and documentation around isolation work at The Company. E.g omitting the pressure monitors in the list over sensitive equipment.
- The isolation competence at The Company is organized in such way that responsible and installer is far away from each other.
- Breaches in instructions and documentation resulted in that the usage of shrinking tube was not documented. The shrinking tube was not noticed during the instruction audit (this is however not required according to instructions).
- Deficiencies in instructions and documentation around testing resulted in that megging was not conducted during circuit control. The megging was not conducted despite it is included in the instructions.
- Breaches in communication in The Company resulted in that relevant information was not considered during OM A.

9. Discussion and Conclusion

9.1. Framework and Delphi assessment

During the work with the thesis it has become very clear that the area of safety and safety culture is rather unexplored. One example of this is the large amount of definitions, another is the generally large variation in the Delphi assessment answers. The most concrete example of this in the Delphi assessment is the answers regarding the role of non-governmental groups when it comes to create a good safety culture (table 13). Relating the answers to Hofstede et al.'s cultural model where values are adopted during the early part of life, unions and likewise should not play a significant role. Though, considering Schein's definition of culture and Lee's definition of safety culture, both discusses the shared values/believes/attitudes. With that in mind, having schools, unions or other groups that share the same basic assumptions, espoused values and perception of safety might in theory affect the safety culture in an organization. One of the participants in the Delphi assessment commented on that; while the organization creates its own culture, a very different national culture might be confusing for the employees.

The answers to the question regarding how to change/improve safety culture in the best way (table 18) were dominated by management's commitment (six out of eight), training in combination with communication/safety meetings and involving everyone in safety work (frequency of three on all three of them). Relating the answers to the framework, focus should be on changing the motivation and capability to work safe. Only two answers are considered related to *Allowed*; 'implementing a comprehensive SMS' and 'assigning safety officers' (both with a frequency of one). The reason why so few focus on *Allowed* is unclear, though, it is possible that the features that can be assigned to *Allowed* is not considered as a part of safety culture, or that it is seen as natural for the other interviewees. Further on, three respondents commented the question to be very extensive, which might imply that full answers were not given.

Relating the answers on the fifth question (table 18) to accidents such as Longford and Fukushima, it is possible that the proven effect of management's commitment on Organization and Work Team level can be connected to the Society level as well, e.g. that close collaboration between organizations and regulatory bodies with a two way communication is required to create a positive safety culture.

The third question (table 14, table 15), regarding the advantages and disadvantages with hard values, gave rather unexpected results. As discussed by e.g. Reason, and shown in accidents, singly using hard and/or lagging indicators as a measure of safety in an organization is not sufficient. However, while some interviewees did declare them as rather useless without other measures or management's attention, others seemed to find them as more or less sufficient measures of safety (culture) as long as one takes the risk of underreporting in to account.

Schein's method for assessing the basic assumptions is adapted to a group and as discussed, an individual's behavior is affected by the group. Due to this, the suggested method in the thesis was interviews and questionnaires when assessing the basic assumptions of individuals. This approach is partly supported by the participants in the Delphi assessment. Five out of eight answer on the first question (table 12) that they consider it sufficient with interviews while the remaining three consider it necessary to use observations as well as interviews and questionnaires. Although the position taken in this thesis is that an individual's behavior is affected to that extent that it is hard to determine if it is due to the individual or to the group, it is considered necessary to conduct further studies in the area of revealing individual's basic assumptions.

Although the majority of the interviewees are positive to the definitions of aspects and the grading scale (table 19), it is not considered sufficient as validation, the number of interviewees is too low and not statistically significant. Considering the definitions of the aspects and the hypothesis, (safety) cultures stability result in that they require long term studies of organizations in order to be validated. To be able to conduct such studies and determine the level of compliance with the definitions, it is necessary to validate the grading scale through more interviews. Though, while the majority of the interviewees were positive to the grading scale, there were several comments on what should be added. In order to make the grading scale more general and gain acceptance in industry, before validation is performed it is considered necessary to conduct further interviews with individuals active in several industries and countries.

Regarding the aspects and their titles that were decided upon in the hypothesis, it is possible that the title *Allowed*, might be misleading. Referring to the forth Delphi assessment question (table16, table 17), regarding the difference between being able and being allowed, neither of the respondents discussed instructions with associated knowledge of them. It is possible that another title would have been more suitable.

Proceeding with the aspects, one might argue that within *Capable*, competence should contain more than the training records and that e.g. experience could be included. This was also commented on by one of the six individuals in the validation group. However, experience regarding safety and procedures can be positive and negative. Describing the features characterizing high/low level of experience and whether it is positive or negative is not considered feasible, why *Capable* is aiming at the documented competence.

Relating the model to the different approaches to safety discussed in the theory section (figure 2), while mainly focusing on the human issue, there are features (e.g. competences and task descriptions) that are suitable in the other approaches as well. As one of the interviewees discussed, (s)he agrees with the aspects under the condition that the plant is in good condition, i.e. the hardware. However, as discussed in the thesis, these features are possible to review as artifacts and can hence be seen as a part of the (safety) culture.

The disagreement regarding the composition, content and features of safety culture may result in that some might question if it truly is safety culture that is measured when using the framework. However, reviewing Lee's and Schein's definitions, it is considered as a measure of the safety culture as long as one has a holistic view of the aspects and societal layer and takes the time into account. Though, Lee's and Schein's definitions aims at organizational (safety) culture and it can hence be discussed to what extent society affects it. This uncertainty is also enlightened by the result of question 2 (table 13) in the Delphi assessment and future work needs to be put on assessing society's effect on the organizational safety culture.

9.2. Testing

The result of the C/S Costa Concordia accident analysis (table 20) is that the Work Team and the master had breaches in the *Motivated* aspect. Relating to the investigation report's conclusion that blamed the human factor and commenting on the passive behavior of the crew on the bridge, the findings are rather similar. However, in order to assess the safety culture it is necessary to have a time perspective which is not the case in this study. Further on, since neither interviews nor questionnaires have been used, it is not possible to reveal the espoused values or the basic assumptions, the result of the analysis must hence be reviewed with caution. As discussed under the evaluation section, revealing an individual's basic assumptions by reviewing their behavior in a group is not considered feasible

why the result on the master's motivational level might not be "true". Commenting on the Calculative grade on *Allowed* and *Capable*, it is possible that other grades would be more appropriate. However, judging from the event description, it is seems like neither instructions nor training would have affected outcome of the event.

Considering the causes discussed by the investigation board in the incident at The Company, there are some causes that were not reviewed in the framework analysis. The framework did neither consider the strained resources nor the sharp edge on the pressure monitors as a cause. However, the framework is not aiming at assessing hardware why this is not considered a breach. Yet, considering the quality of equipment as artifacts, it is possible that a discussion of the condition of the facility and equipment should be included on the *Allowed – Organization* level. Regarding the strained resources, it is stated that it hampered the desired systematic work around isolation, it is however not revealed in what way, e.g. low amount of personnel or absence of equipment. Beside the fact that the decision to use shrink tube was taken under time pressure (yet several experts were consulted), no evidence of lack of resources are found. However, it is possible that the strained resources are manifested in the poor instructions that are discussed by both analyses.

The third root cause discussed by the investigation board was that the usage of shrinking tube was due to inadequate risk assessment, communication and understanding of each-other's work. Considering that the correct instances were consulted and that there is no comment in the event description that instructions would not have been followed, it seems like there was breaches in the SMS for how hardware modifications and communication around it shall be conducted. This is also supported by the contributing cause stating that breaches in communication resulted in that relevant information was not present during OM A.

Considering the contributing causes, breaches in instructions are identified in both analyses. However, while the framework analysis considers the motivation and not the megging instructions being the problem, the investigation report only discusses the instructions as the cause to why megging was not performed. It is possible that the interviews conducted by the investigation board revealed information regarding this that was not presented in the event report.

The way the isolation competence was organized in The Company has not been considered in the framework analysis. It is not presented in the investigation report in which way this contributed to the accident. As for the decision to assign the not conducted megging to the instructions, it is possible that the investigation board possess information not presented in the event description that justifies their conclusion.

Finally, it shall be stated that while *Allowed – Work Team* received the lowest grade (Reactive), no grade above Calculative was given. Judging from this event, work must be put in to improving all six squares. However, as for the C/S Costa Concordia accident, the analysis is based on one event and it is hence not possible to conclude if there is an issue with the culture or if the events were situation based. Further on, although a complementary interview have been conducted, it would have been necessary to interview all the persons directly involved in the event in order to make an accurate analysis of the culture.

Relating the incident analyzes to the hypothesis of the project, it is considered to neither been proven nor proven wrong. In order to do so, it is found required to fully test the framework on full scale organizations in long-term studies and assess if there are any correlation between the safety culture grades on the different societal levels and the safety performance in the organization. To be able to test the framework fully, tools such as questionnaires must be developed and associated to the grading of

the safety culture. Further on, in order to test the hypothesis, it is necessary to develop a way of grading safety that consider all aspects of safety, e.g. technical, procedural and human issues.

9.3. Conclusion

While the framework analyses of the incidents to a large extent comes to similar conclusions as the investigation reports, it is not possible to conclude that the hypothesis is true with the current definitions of the aspects. Testing the hypothesis requires the use of the framework in long term studies comparing how the safety culture and the safety performance in organizations correlate over time. In order to conduct such studies, further work must be put in to development of evaluation tools.

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Appendix A. Parker et al.'s grade definitions

	Pathological	Reactive	Calculative	Proactive	Generative
Benchmarking, Trends and Statistics	Compliance with statutory HSE reporting requirements, but little more. Benchmarking only on finance and production.	Try to respond as other companies do, and worry about the cost of accidents, and their placing in the "safety league". Statistics report the immediate causes of accidents.	Benchmark on incidents and accidents. Display lots of data publicly throughout the organization. Focus on current problems that can be measured objectively and summarized numerically.	Benchmark against others in the same industry, driven by management. Try to be the best in the industry. Look for trends, understand them and use them to adapt strategy. Explain findings to supervisors.	Benchmark outside the industry, using both hard and soft measures. Involve all levels of the organization in identifying action points for improvement.
Audits and reviews	Unwilling compliance with statutory inspection requirements. Audits are mainly financial. HSE audits are unstructured, and only after major accidents.	Accept being audited as inescapable, especially after serious or fatal accidents. No schedule for audits and reviews, as they are seen as a punishment.	There is a regular, scheduled audit program. It concentrates on known high hazard areas. Happy to audit others, but being audited is less welcome. Audits are structured in terms of management systems.	Extensive audit program including cross-auditing within the organization. Management supervisors realize that they are biased and welcome outside help. Audits are seen as positive, if painful.	Full audit system running smoothly with good follow up. Continuous informal search for non-obvious problems with outside help when needed. There are fewer audits of hardware and systems, and more at the level of behaviors.
Incident/ accident reporting, investigation and analysis	Many incidents are not reported. Investigation only takes place after a serious accident. Analyses don't consider human factors or go beyond legal requirements. Protect the company and its profits.	There is an informal reporting system and investigation is aimed only at immediate causes, with a paper trail to show an investigation focuses on finding guilty parties. There is little systematic follow up and previous similar events are not considered.	There are procedures producing lots of data and action items, but opportunities to address the real issues are often missed. The search for causes is usually restricted to the level of the local workforce.	There are trained investigators, with systematic follow-up to check that change has occurred and been maintained. Reports are sent companywide to share information and lessons learned. There is little creativity in imagining how the real underlying issues could affect the business.	Investigation and analysis driven by a deep understanding of how accidents happen. Real issues identified by aggregating information from a wide range of incidents. Follow up is systematic, to check that change occurs and is maintained.
Hazard and unsafe act report	There are no reports.	Reporting is simple and factual. Focus is on determining who or what caused the situation. The company does not track actions after reports.	Reports follow a fixed format for categorization and documentation of observations. Number of reports is what counts. The company required complete forms without blanks.	Reporting looks at "why" rather than just "what" and "when". Quick submission of reports is appreciated, and blanks in forms can be filled in later. Management sets reporting goals.	All levels actively access and use the information generated by reports in their daily work.

Work planning including PTW, journey management	There is no HSE planning overall. What work planning there is concentrates on the quickest, fastest, and cheapest, execution.	HSE planning is based on what went wrong in the past. There is an informal general planning process, based primarily on managing the time taken for a job.	There is a lot of emphasis on hazard analysis and PTW. There is little use of feedback to improve planning, but people believe that the system is good and will prevent accidents.	Planning is standard practice, with work and HSE integrated in the plan. Plans are followed through and there is some evaluation of effectiveness by supervisors and line management.	There is a polished planning process with both anticipation of problems and review of the process. Employees are trusted to do most planning. There is less paper, more thinking, and the process is well known and disseminated.
Contractor management	Get the job done with minimum effort and expense.	The company only pays attention to HSE issues in contracting companies after an accident. The primary selection criterion is price, but only poor safety performance has consequences for choice of contractors.	Contractors meet extensive pre-qualification requirements, based on questionnaires and statistics. HSE standards are lowered if no contractor meets requirements. Contractors have to get up to speed on their own.	HSE issues are seen as a partnership. Pre-qualification is on the basis of proof that there is a working HSE-management system. Joint company-contractor safety efforts are observed and the company helps with contractor training.	No compromises to work quality. Find solutions together with contractors to achieve expectations even if this means postponing the job until requirements are met.
Competency/training – are workers interested	Training is seen as a necessary evil. Attend training when it is compulsory by law. Workers don't mind exchanging a harsh working environment for a couple of hours training off the job.	Training is aimed at the person "If we can change their attitude everything will be all right". After an accident money is made available for specific training programs. The training effort diminishes over time.	Competence matrices are present and lots of standard training courses are given. Acquired courses knowledge is tested. There is some on-the-job transfer of training.	Leadership fully acknowledges the importance of tested skills on the job. The workforce is proud to demonstrate their skills in on-the-job assessment. Training needs start to be identified by the workforce.	Issues like attitudes become as important as knowledge and skills. Development is seen as a process rather than an event. Needs are identified and methods of acquiring skills are proposed by the work force, who are an integral part of the process rather than just passive receivers.
Work-site job safety techniques	There are no techniques applied. Look out for yourself.	After accidents a standard work-site hazard management technique is bought in, but there is little systematic use after initial introduction.	A commercially available technique is introduced to meet the requirements of the management system, but leads to little action. Quotas are used to demonstrate that	Job safety analysis/job safety observation techniques are accepted by the workforce as being in their own interest and they regard such methods as	Job safety analysis, as a work-site hazard management technique, is revised regularly in a defined process. People (both workers and supervisors) are

			the system is working. Nothing else is used.	standard practice.	not afraid to tell each other of operations.
Who checks safety on a day-to-day basis?	There is no formal system, so individuals take care of themselves as they see fit.	External inspections check sites after major incidents. Cursory site checks are performed by line supervisors/management when they are visiting, mostly after incidents or inefficiencies. There is no formal system for follow up.	Site activities are regularly checked by the line management, but not on a daily basis. Inspections aim at compliance with procedures.	Supervisors encourage work teams to check safety for themselves. Managers doing walk-rounds are seen as sincere. They engage employees in dialogue. Internal cross-audits take place, involving managers and supervisors.	Everyone checks for hazards, looking out for themselves and their work-mates. Supervisor inspections are largely unnecessary. There is no problem with demanding shutdowns of operations.
What is the size/status of the HSE department?	If there is a department, it consists of one person or a small staff in the HR department.	The department is small and has little power. It is seen as a career backwater, and once in it is har to get out. The staff is on call constantly, but usually very much in the background. The department is seen as a police force.	HSE positions are given to middle managers with good background who can't be placed elsewhere. It is a large department with some status and power, mainly performing number crunching and sending people on training courses. The HSE manager reports to someone in a position of operational authority.	HSE seen as an important job, given to high fliers. HSE professionals a recruited directly and advisors are appreciated by the line. All senior people in operations must have HSE experience. The HSE manager reports directly to the top management of the company.	There may not be an HSE department because it is not needed, as the safety culture is right. HSE responsibilities are distributed throughout the company. If there is a department it is small but powerful, having equal status with other departments.
What are the rewards of good safety performance?	None is given or expected - staying alive is reward enough. There are only punishments for failure.	There are disincentives for poor HSE performance. Safety understanding that positive behavior can be rewarded has not yet arrived. Managers' bonuses tied to LTI performance.	Some lip service is paid to good safety performance. Safety awards such as T-shirts or baseball hats are made. There are safety competitions and quizzes TRCF is used when calculating bonuses.	There are some rewards and good performance is considered in promotion reviews. Evaluation is process-based rather than on outcomes.	Recognition itself seen as high value. Good HSE performance is intrinsically motivating.

Who causes accidents in the eyes of management?	Individuals are blamed, and it is believed that accidents are a part of the job. Responsibility for accidents is seen as belonging to those directly involved.	There are attempts to remove "accident-prone" individuals. It is believed that accidents are often just bad luck. The responsibility of the system for accidents is considered but has no consequences.	Fault machinery and poor maintenance are identified as causes as well as people. There are attempts to reduce exposure. Management has a Them rather than Us, mentality and takes an individual rather than system perspective.	Management looks at the whole system, including processes and procedures when considering accident causes. They admit that management must take some of the blame.	Blame is not an issue. Management accepts it could be responsible when assessing what they personally could have done to remove root causes. They take a broad view looking at the interaction of systems and people.
What happens after an accident? Is the feedback loop being closed?	After an accident the focus is on the employee, and they are often fired. The priority is to limit damage and get back to production	Line management is annoyed by "stupid" mistakes. After an accident reports are not passed up the line if it can be avoided. Warning letters sent by management.	Workforce reports their own accidents but maintain distance with contractor incidents. Management goes ballistic "what will this do to our statistic"?	Management is disappointed, but asks about the wellbeing of those involved. Investigation focuses on underlying causes and the results are fed back to supervisor level.	Top management is seen among the people involved directly after an accident. They show personal interest in individuals and the investigation process. Employees take accidents to others personally.
How do safety meetings feel?	Meetings if any seen as a waste of time. They are run by the boss or supervisor and are felt to be a case of going through the motions. Conversation often turns to sport.	Meetings are attended reluctantly. They provide opportunities to point the finger of blame for incidents and form a standard response to an accident. Toolbox meetings may be dominated by non-work issues	Meetings are like textbook discussions about company policy with limited interaction. The regular scheduled meetings feel like overkill. Toolbox meetings are run on a strict agenda.	Meetings feel like a genuine forum for interaction across the company. At lower levels all meetings are safety meetings and are used to identify problems before they occur.	Meetings can be called by any employee, taking place in a relaxed atmosphere, and may be run by employees with managers attending by invitation. Toolbox meetings are short and focused on ensuring everyone is aware of what problem might arise.
Balance between HSE and profitability	Profitability is the only concern. Safety is costly and the only priority is to avoid extra cost.	Cost is important, but there is some investment in preventive maintenance. Operational factors dominate.	Safety and profitability are juggled rather than balanced, with the line spending most of its time on operational issues. Line managers know how to say the right things, but do not always walk their own talk. Safety is seen as discretionary expenditure. If all	The company tries to make HSE the top priority, while understanding that HSE contributes to financial return. The company is quiet good at juggling the two, and accepts delays to get contractors up to standard in terms of safety. Money still counts.	They are in balance so that this becomes a non-issue. Management believes that HSE makes money. The company accepts delays to get contractors up to speed.

			contractors are unacceptable, the least bad is taken.		
Is management interested in communicating HSE issues with the workforce?	Management is not interested apart from telling workers not to cause problems.	The "flavor of the month" safety message is passed down from management. Any interest diminishes over time as things get "back to normal".	Management shares a lot of information with workers and has frequent safety initiatives. Management does a lot of talking but there are few opportunities for bottom up communication.	Manager realize that dialogue with the workers is desirable so a two-way process is in place. Asking as well as telling goes on. The emphasis is on looking out for each other in the workplace.	There is a definitive two-way process in which management gets more information back than they provide. The process is transparent. It's seen as a family tragedy if someone gets hurt.
Commitment level of workforce and level of care for colleagues	Who cares as long as we don't get caught? Everyone looks out for themselves	"Look out for yourself" is still the rule. There is a voiced commitment to care for colleagues, after accidents by both management and workforce, but this diminishes after a period of good safety performance.	There is a trickle down of management's increasing awareness of the cost of failure. People know how to pay lip service to safety, but practical factors may prevent complete follow through.	Pride is beginning to develop, increasing the workforce's commitment to HSE and their care for colleagues, but the feeling is not universal.	Levels of commitment and care are very high and are driven by employees who show passion about living up to their aspirations. Standards are defined by the workforce.
What is the purpose of procedures?	The company makes HSE procedures out of necessity. They are seen as limiting people's activities to avoid litigation or harm to assets.	The purpose of HSE procedures is to prevent individual incidents recurring. They are often written in response to accidents and their overall effect may not be properly considered in detail.	There are many HSE procedures, serving as "barriers" to prevent incidents. It is hard to separate procedures from training.	HSE procedures spread best practice but are seen as occasionally inconvenient by a competent workforce. A limited degree of non-compliance is acceptable.	There is trust in employees that they can recognize situations where compliance should be challenged. Non-compliance to HSE procedures goes through recognized channels. Procedures are refined for efficiency.

Appendix B. Grades adapted to the framework

Appendix B. a) Society

Allowed

Pathological;
There are no laws or requirements for the industry regarding construction and operation of plant, safety measures or risk reduction.

Reactive;
Laws based on plant construction and practiced operations. Safety measures and risk reduction are required from the company by regulatory bodies after large accidents.

Calculative;
Laws based on plant construction, practiced operations and regular risk identification and elimination on the site, or there exists clear criteria to be fulfilled by the organization in order to meet laws and regulations.

Proactive;
Laws affecting the organization are based on international expectations regarding plant construction, operation and regular risk identification/elimination, or clear criteria to be fulfilled by the organization in order to meet laws and regulations. The organization is required to provide an action plan for how to improve safety.

Generative;
Laws for the industry are based on international standards for construction, operation and regular risk identification/elimination, or clear criteria to be fulfilled by the organization in order to meet laws and regulations. Organizations are required to provide an action plan for how to improve safety, both hard and soft values such as culture and climate.

Capable

Pathological;
There are no schools that provide required competence to deal with laws and regulations. Competence has to be obtained by consultant companies or foreign schools.

Reactive;
There are some competence provided in the area, however, not enough to meet laws and regulations.

Calculative;
Competence is sufficient to meet laws and regulations, enough competence to operate the site.

Proactive;
Competence is sufficient to meet and go beyond regulations. There is research in the area, and education providers are through collaboration with industry developing training and education. There is competence to develop the business.

Generative;
There is education that is developed to meet the business need, the competence provided is very deep and of high international standard. It is collaboration between schools and industry with many guest

lecturers and field trips. Research in the area is front end and education is of high international standard.

Motivated

Pathological;
There are no systems for dealing with companies that deliver poor or no result/measures. Accident analyses, if conducted at all, by regulatory bodies are aiming at technical issues and do not consider root causes. There are no follow up for controlling that changes have been made or risk eliminated, information is not spread to other businesses or organizations. There are no audits conducted by regulatory bodies. The industry has very low status, is mistrusted and constantly questioned in/by society.

Reactive;
There is a framework for reprimanding companies, however, it is not uncommon that companies who deliver poor result/measures slips away. Accident investigation aims at finding the guilty party. Audits are conducted by regulatory bodies after major accidents. The industry is generally mistrusted by society and accidents are followed by mass protests.

Calculative;
The framework for reprimanding companies that do not fulfill the regulations is in use. No progressive punishment for frequently failing in delivering (good) measures. Accidents result in that the organization is fined or shut until technical issues are solved, the organization is under observation for a time afterwards but other organizations in the same business are, apart from some warning letters, not affected. The industry is generally considered necessary but unwanted by society.

Proactive;
Companies are punished with fines or shut plant for not delivering good measures, progressive punishment for frequently delivering poor measures. After poor results and accidents, an action plan for how to avoid similar events in the future are required and implementation of it is followed up. Information is spread to other organizations in the same business. Other plants and businesses might be audited after accidents or larger near misses on other plants. There is work with improving safety in different ways, although there is no or little consideration of other industries. The industry is considered trust worthy by society.

Generative;
Companies are punished with fines or shut plant for not delivering good measures, both hard and soft, progressive punishment for frequently delivering poor measures. After poor results and accidents, an action plan for how to avoid similar events in the future are required and implementation of it is followed up. The development of safety is not tied to one industry, lessons learned in one industry is used to improve safety in other industries. The industry is considered as a leading example and a natural part of society.

Appendix B. b) Organization

Allowed

Pathological;
If there is a safety management system that is adapted to the current structure, it aims at compliance with laws and regulations. If there are responsibilities, they only exist on paper and are poorly known in the organization. If there are any safety measures, they are technical and lagging. There is no plan

for how to improve safety. Systems and procedures are neither well defined nor well known. Responsibilities and structures are not changed after accidents.

Reactive;
Responsibilities and procedures regarding safety issues are unclear, poorly known and non-updated to organizational structure and/or equipment until an accident occurs. No instructions for how to maintain or develop the safety level. Measures are primarily lagging and considering technical issues, no plan for how to evaluate result and finding underlying causes. Procedures and responsibilities stem from accidents in the past and there are no plans for how to improve and develop safety.

Calculative;
The safety management system is adapted to the current structure of the organization and responsibilities are known by ones directly affected by it, in case of uncertainties, it is easy to obtain the required information. Safety is dealt with a "checklist" mentality where measures and procedures are described in detail with clear boundaries. There are no instructions for how to follow up safety or how to improve the system. Measures are still mainly lagging hard values such as Lost Time Injuries (LTIs) and number of reports.

Proactive;
Responsibilities and instructions in the safety management system are detailed and adapted to the current organization and understood by through the organization. Safety measures are mainly technical, both leading and lagging and there are instructions for how to interpret and use them. The safety management system includes procedures and instructions for how to follow up, enhance and improve safety. The safety management system contains instructions for how safety related information (e.g. near-misses) shall be disseminated in the organization.

Generative;
Responsibilities and instructions in the safety management system are adapted to the current organization and understood by the entire organization. Instructions for how to improve safety involve all levels of the organization. Safety measures include both hard and soft measures (e.g. attitudes and trust) and there are instructions for how to interpret measures and improve them.

Capable

Pathological;
Training is provided by the organization only if it is required by law. There is no examination, presence during lectures considered enough. No follow up afterwards to control if competence has contributed to increased safety in any way, no development of training. There are no methods or instructions for identifying needs of training or breaches in competence.

Reactive;
Training needs are identified by accidents and aims at the individual or group involved in the event. Training might be examined orally or written, there are no follow up for evaluating if it have resulted in any changed behavior or to improve the training. There is no thorough "introduction" when people start a new job.

Calculative;
Training needs are mainly identified by competence matrices and time since last training sessions, training is standard courses associated to the competence matrix. Competence is tested with oral or written examination and practically when suitable. Training is evaluated through questionnaires regarding way of teaching, no evaluation of content or changed habits. When people start a new job,

there is an “official” short introduction to tasks and responsibilities held by the team leader. After reorganizations it is controlled that people have gone through the required standard training practices for the new tasks and responsibilities.

Proactive;
There are some training needs identified with competence matrices with associated standard training, managers and to some extent work force start to identify training needs. Practical and theoretical knowledge is tested and there are thorough evaluations for improving course content and way of teaching. There are follow ups for assessing if the training has resulted in the desired improvement. When people start a job, there is a through introduction to tasks and responsibilities, if competence is missing training is given.

When there are reorganizations there are evaluations for assessing if current knowledge is sufficient or if new training has to be developed and conducted.

Generative;
There are some training needs identified with competence matrices with associated standard training, managers and work force identify training needs, both technical and attitudes, and training practices is developed in collaboration with the participants. Practical and theoretical knowledge is tested twice, first directly after finishing training and secondly a few months later, assessing if training resulted in the desired outcome. There are thorough evaluations for improving course content and way of teaching.

Regularly evaluations of the competence in the organization are performed without being proceeded by reorganization. When people quit their job, there is a process for preserving and disseminate his/hers experience to the organization.

Motivated

Pathological;
There are no actions for improving safety, possible policies and statements only exist on paper and are not reflected in the daily work. After accidents people involved are punished.

Reactive;
There are targets for hard values such as Loss Time Injuries (LTI) and number of reports. Rewarding system is based on few accidents/reports and not operating in a safe way. Not operating according to procedures are punished only when it result in an accident. Safety measures that are prioritized are hard and lagging values, there is no attention paid to soft and leading indicators. Reward system and other actions by management are favoring cost over safety.

After accidents or shutdown of the plant it is priority to start production instead of finding the causes for shutdown.

Calculative;
There are policies and statements from management communicated to the work force. Communication is one-way from management and there is little effort for controlling that policies and statements are followed. It is no work for evaluating procedures or controlling that implemented systems are working, safety work is static and there are little effort in improving safety. There are lots of safety measures taken, the ones given most attention are still lagging hard measures. Safety is stated as a high value but not always shown in action. Safety is favored when it does not contradict production.

Proactive;
Safety policies and statements are communicated to the workforce by management. Management is present and visible and there is a two way communication between workforce and management. There are regularly acts aiming at encouraging, develop and enhance safety mainly technical and procedural. Large amount of safety measures, both leading and lagging, all measures taken are considered important and acted upon. The organization is looking at other companies in the same industry to learn and develop. There is no contradiction between safety and production.

Generative;
The organization has policies and statements that are implemented in the organization and reflected in the daily work. Safety is considered in every decision and there are a large number of actions for improving all aspects of safety, attitudes as well as technical and procedural. Safety is of as high priority as production. The organization looks at other industries and tries to adapt their safety knowledge to their business. Decisions regarding safety are made together with the workforce.

Appendix B. c) Work team

Allowed

Pathological;
There are no known instructions or responsibilities. If there are any instructions, they are undetailed, not updated and there is no general knowledge about them.

Reactive;
There exist instructions for tasks, procedures and responsibilities, they are vaguely known and there is no general knowledge how to find the information. The instructions are un-detailed, not updated to current group structure and/or equipment used. After an accident the instructions and responsibilities are updated.

Calculative;
There are instructions regarding task, procedures and responsibilities that are known by the majority of the group and incase of uncertainties the information is accessible, are up to date and adapted to the current group structure and equipment. The instructions are detailed and describe procedures, hazards/risks, required equipment and competences. There are instructions for how to communicate safety in the work team and between shifts.

Proactive;
Instructions and responsibilities are detailed, updated and understood by the group. Instructions regarding operations include how the procedure might affect the system, surrounding factors that can affect the procedure and general hazards and risks in the area to be aware of. Instructions also include how to control that a task has been conducted in the right way.

There are instructions for how to raise safety related questions for improving and develop safety. There are instructions for how to communicate safety issues between shifts and how to disseminate information in the organization.

Generative;
The instructions for the group are not only technical and procedural but also describe how to behave in different situations. There are very good understanding in the group regarding responsibilities, tasks and how to act during procedures, uncertainties are controlled and eliminated.

Capable

Pathological;
The competence in the group is not sufficient to perform assigned tasks. Competence is not considered when tasks are assigned, training is attended when it is compulsory. There is no attempt to increase competence in the group, neither by learning from each other nor by requesting training. Finding new group members aim at personality, not competence.

Reactive;
There are some competence in the group but not sufficient to meet the required competence to perform task. Experience is considered more important than competence. The current competence is considered enough until an accident occurs, the common understanding is that accidents are due to personality and not to poor competence.

Calculative;
The competence in the group meets the required needs to perform the group's tasks. When tasks are assigned, competence is reviewed. If competence is missing, "exceptions" are made and the task is carried out without the competence. There is some effort to increase the competence in the group by asking more experienced personnel, no attempt to get "official" training.

Proactive;
The competence in the group goes beyond the required technical needs. If competence is missing, it is reported and the task is not performed until new instructions have arrived. There is a will to learn both from team members and by "official" training. Some training needs are identified by the work force. The total competence of the group is of high value and the group consist people with different background and experience.

Generative;
The competence in the group goes beyond technical requirements, and there is knowledge regarding human factors which is considered when assigning tasks. There is a positive attitude toward training and the group is the main source of identified training needs.

Motivated

Pathological;
Official leadership in the group is not visible, supportive or present. The general attitude is that safety procedures are to no good. Even when there is time and resources to operate safe, it is ignored.

Reactive;
Official leadership is not or rarely visible and present and pay no or little attention to safety related issues, there is no control of procedures being followed or reprimands for not working according to instructions, main task when present is to maintain production. There is one way communication telling group members to work safe. Safety information is not or poorly communicated in the group. Questions and comments regarding poor safety is ignored or mocked, the general attitude is that one should act as told and not ask questions. Safety procedures might be followed in case of time.

Calculative;
Leadership is visible and present when required or told to. Controlling that procedures are followed during the daily work and comment (reprimands are rare but do occur) if instructions are not followed, make "exemptions" if it lead to maintaining production or speeding up startups when time is short. Communication is still manly one-way, telling worker to follow instructions. Within the group are safety information communicated according to instructions (e.g. handovers, reports and meetings). There is no active work by leadership to find uncertainties or creating an environment where questions

are welcome. The attitude in the group is that safety is important when time is available and that questions regarding safety are not necessary to discuss in group.

Proactive;
Leadership is present and visible on site without being told to and tries to enhance and motivate safety through various acts. Working according to procedures is acknowledged while not working according to procedures is not accepted, regardless of consequences for production. There is a two way communication where leadership welcomes questions and suggestions for improving safety. Safety communication goes beyond instructions, both in content and in frequency. Acting in a safe way and according to procedures is not questioned and when someone does not work according to instructions it is commented by colleagues. The workforce realizes that working safe is important and is motivated to do so, although the general perception is that safety procedures are cumbersome.

Generative;
Leadership is more or less constantly visible and present, always promoting safe behavior. Procedures are always followed and there is a two way communication regarding how to improve safety. The workforce strives to work as safe as possible and have no problem to go beyond instructions and procedures.

Appendix B. d) Individual

Allowed

Pathological;
The individual feels no obligation to use instructions or undertake responsibilities/the instructions and responsibilities are poorly described and unknown by the individual.

Reactive;
There exist some instructions that are known and accepted by the individual, the instructions are poorly defined and not updated to equipment and/or the individuals knowledge. Responsibilities are to a large extent not documented and poorly known.

Calculative;
Instructions, procedures and responsibilities are well defined, updated, easy to access and to a large extent known and accepted by the individual, describing his/hers tasks, responsibilities and who to turn to in case of questions. There is a clear framework for safety but little or no instructions for development and suggestions exist/are known to the individual.

Proactive;
Instructions, procedures and responsibilities are well defined, updated, easy to access and well known and accepted by the individual. The individual have a good knowledge regarding procedures and responsibilities in his/hers surrounding. The instructions for tasks include descriptions of what can go wrong, and describes indicators for detecting this. There exist instructions and procedures for how to improve safety and making suggestions that are known to the individual.

Generative;
Instructions and responsibilities include attitudes and behavior as well as technical issues. Instructions describe how tasks and procedures affect, and is affected by, other operations and are well understood and fully accepted by the individual. Who to turn to and what to do in case of questions and safety inquiries are well known.

Capable

Pathological;
The individual is not competent to perform assigned tasks, does not regard competence as necessary, avoids training if possible, is a passive receiver in case of mandatory training and do not use the information from training.

Reactive;
The individual possesses some competence, but not sufficient to perform most assigned tasks, it is either out dated or not completed. Training is required for individuals that causes accidents, sees training sessions as a break from work and is a passive receiver.

Calculative;
Competence meet the stated needs to perform tasks, sees training as necessary to be allowed to perform tasks. General attitude is to pass examination requirements but have no interest in learning "more than necessary". Evaluate training when asked to but do not provide any feedback otherwise. When missing competence it is not necessary to consult books or experts but asking a colleague is sufficient, if no answers are found task are carried out any way.

Proactive;
Possesses competence to meet the stated needs to perform tasks and have a wider knowledge and interest in the area. Training and competence is important and training is attended even when optional, is an active receiver during training and comment on breaches in training, both teaching and content. When competence is missing, handbooks and experts are primary choice otherwise ask multiple colleagues to control that information is correct, if no good answer is found, task will not be carried out.

Generative;
Have a competence that goes beyond the technical requirements for assigned tasks, have a good understanding of the entire process, both practical and theoretical. Competence is very important to the individual. Makes suggestions of suitable training for him/her-self and the entire group, is an active receiver and makes suggestions on how to improve training. In case of missing competence and no experts, framework or handbooks are available, no further actions will be taken.

Motivated

Pathological;
There is a feeling that safety procedures are to no good, they are time consuming and unnecessary. Accidents and errors are a part of the job. Getting the job done with minimum effort is the goal.

Reactive;
Procedures are too cumbersome and not necessary to follow unless audited, there is no or very little interest in improving safety and there is a feeling that no one would care any way. There is no feeling that one can affect the system.

Calculative;
Safety is important and procedures should be followed as long as possible, it is okay to make "exceptions" in case of little time or short of personnel. Procedures considered redundant tend to be subject to "exceptions" more often. Safety is purely technical and procedural. Safety is a management issue and is not possible to affect. Not having accidents is an evidence of a working safety system.

Proactive;
Safety procedures are important and must be followed. Although some procedures are time consuming and could be improved they are there for a reason and provide a safe working environment. When

there is procedures missing or do not work, it is motivation to put them in place and make them work. It is important to work in a safe way. Not having accidents is not alone an evidence of good safety, safety is accomplished when people work in a safe way.

Generative;
Following safety procedures are important but they are sometimes not good enough. All procedures can be improved and it is important to work with the attitude regarding safety in the group to establish good safety. An accident is always around the corner and safety is accomplished when procedures are followed and human factors have as positive influence on the system as possible

Appendix C. Comment and conditions to the aspects and adapted grading

Appendix C. a) Conditions and comments to question 1.

- The societal levels are not independent of each other and it is probably not feasible to reach good results if one level is breaching.
- Agree under the condition that the condition of the plant is good.

Appendix C. b) Conditions and comments to question 2.

- There should be more emphasis on learning from near-misses and incidents on all societal levels.
- The grade descriptions focus too much on personal safety.
- Allowed; Work Team: The structure of the information system should be included in the grade description.
- Capable; Society and Organization: The competence of senior management and decision makers in regulatory bodies should be discussed on Organization and Society level respectively.
- Capable; Organization: The way organizations conduct training should be more thoroughly discussed, e.g. computer based training.
- Capable; Organization: The organization's general competence and its behavior around competence when hiring new personnel should be included.
- Capable; Work Team: The documentation of competence requirements and actual competence in the group should be included in the grade description.
- Capable; Individual: The individual's participation in development of training and education should be included earlier than on Generative.
- Capable; Individual: The individual's knowledge of risks and hazards should be more thoroughly discussed.
- Capable; Individual: The individual's experience should be discussed.
- Motivated; Society: The communication and collaboration between organizations and regulatory bodies should be included.
- Motivated; Organization: Decisions are always taken in with employees.
- Motivated; Work Team: The Work Team's participation in developing and improving procedures should be discussed.
- Motivated; Individual: On higher grades, the individual care for colleagues within the entire organization.

Appendix D. Accidents

Appendix D. a) BP Texas City refinery

At 13.20 on March 23, 2005, an explosion occurred during a startup of the ISOM-unit at BP's refinery in Texas City. The raffinate splitter was overfilled and pressure release devises were opened, resulting in that flammable liquid was released from a blow down stack without a flare. The flammable liquid led to an explosion, killing 15 and injuring 180 (74).

The interested reader is referred to the investigation report (75).

Appendix D. b) Chernobyl

On April 26, 1986, there was an explosion in unit 4 in the nuclear power plant in Chernobyl. The accident occurred during an experimental assessment of the electrical system that controls the reactor when the reactor was shut down due to maintenance. Violating safety regulations, operators turned off important control mechanisms and made it possible for the reactor to go to an unstable condition. A rapid power increase caused the explosion. (76)

Two workers was killed due to none radiative injuries (77) and within three month after the disaster, 28 others died from injuries caused by the accident (76).

Appendix D. c) Esso Longford gas plant

At 12.26 on September 25, 1998, a pump feeding hot oil to a heat exchanger was restarted after a few hours offline. The absence of hot oil had resulted in that the temperature in the heat exchanger was decreased from the regularly $100°C$ to -$48°C$. When pump was restarted and the hot oil reintroduced, the metal in the heat exchanger cracked and released hydrocarbons to the atmosphere. The hydrocarbons were ignited and the explosion that followed killed two and injured eight (78).

The interested reader is referred to the investigation report (79).

Appendix D. c) Flixborough

At 16.53 on June 1, 1974, a temporary 20-inch bypass system that was not properly modified, ruptured, resulting in that a large amount of cyclohexane was released, forming a vapor cloud. The vapor cloud was ignited with an explosion as a result, killing 28 and injuring 36 (80).

The interested reader is referred to the investigation report (80).

Appendix D. d) Piper Alpha oil rig

On July 6, 1988, a temporary flange at the Piper Alpha oil rig in the Norse sea started to release flammable gas which was ignited, resulting in an explosion. The explosion led to a fire, which was exacerbated by other platforms connected to the same pipeline grid that fed the fire with oil. The explosion and fire resulted in that 167 out of the 226 on the platform died (2).

The interested reader is referred to the Cullen report.

Appendix D. e) TEPCO Fukushima nuclear plant

On March 11, 2011, an earthquake resulted in that offsite electricity was lost. The tsunami that followed the earthquake ruined the emergency diesel generators, resulting in that only one of the six units had sufficient power. The tsunami also damaged buildings, resulting in that large amounts of radioactive material were emitted to the surrounding environment (81).

The interested reader is referred to the investigation report (82).

Appendix D. f) Three Mile Island nuclear plant

On March 28, 1979, a large number of maintenance failures resulted in that heat was not removed from the reactor core, resulting in increased temperature and pressure. The pilot-operated release valve was opened to lower the pressure, however, the valve did not close as it should. This resulted in that more than one third of the radioactive water from the primary cooling system was pouring out in the containment building. Hydrogen gas was formed and released through the opened valve causing an explosion in the containment building (83).

The interested reader is referred to the investigation report (83).

Appendix D. g) USS Vincennes

On July 3, 1988, a civilian airplane from Iran Air was shot down by USS Vincennes after the commander and his team had mistaken it for a hostile, resulting in that all 290 passengers died (84).

The interested reader is referred to the investigation report (85).

Appendix E. Event description of the C/S Costa Concordia accident

The C/S COSTA CONCORDIA left Civitavecchia port at 19:18 hours of 13th January 2012 heading to Savona with 3206 passengers and 1023 crew members.

Prior 21:00, The most authoritative of the Officers (1st Deck Officer,) had before the arrival of the Master strongly criticized the decision to follow a route so close to the shore, calling it a true madness.

The staff on duty on the bridge is made from 1 Deck Officer, holder of the duty, from the 2nd Deck Officer (alongside the 1st to handover), from the 3rd deck officer, an Apprentice and the Helmsman.

At 21:00:10, in position 42 ° 18'25 "N - 011 ° 10'48" E (230 ° detection of Punta Secca del Giglio island at a distance of 4.2 miles), and is following a route of 302 ° at a speed of 15.8 knots.

At 21:03 the ship starts a series of yaws to the left ending at 21:11:35 in position 42 ° 19'18 "N 011 ° 06'57" E where route takes 279 ° and a speed of 16 knots, the bow of the ship is directed to the Giglio island.

At 21:19:02 the 1st Deck Officer contacts by phone the Master, as per the instructions given after the departure from Civitavecchia, informing him that are to stay at 6 miles from the Giglio island and that will reach the beam at 21:44.

According to the course planned before departure and speed assumed the ship would reach the point of turn fixed to pass the island of Giglio near the coast at about 21:39.

It is noted that on the bridge are also present the Chief Purser, the Metre and the catering services Manager.

At 21:34:36 the Master comes on the bridge and orders the helmsman to move the rudder in manual mode.

At 21:36:02 the 1st Deck Officer ordered the helmsman to come alongside for 285 and 290 degrees after about 1 minute.

From 21:37:11 to 21:38:47 Master is engaged in a phone conversation with a person and ask him about the safe distance from the coast of Giglio there is a safe depth enough to pass, he replies that it is safe till 0,3/0,4 miles away from the island.

At 21:36:35 (VDR) Masters orders to set on radar a distance circle of 0.5 miles.

At 21:39:14, with a 290 heading, the Master takes the command of the watch.

At 21:39:30 with speed 3.15 Master orders the helmsman to go for 300, and at 21:40:00 orders to increase to 16 knots and then to pull "gently" to 310 °.

Till this point the ship is still on the course as planned and the radar displays a VRM at 0.5 miles. The bow heads towards "Punta Capo Marino" and the ship proceeds, at a distance of 1.35 miles and a speed of 15.4 knots.

The Master now gives orders to the helm for "bows" moves away from the planned course, starting a yaw to starboard wider than planned, thus approaching Giglio island.

At 21:40:48 the Master orders, in English, *".. 325 .."* the helmsman answers, to confirm the order *".. 315 .."*, the First Deck Officer intervenes to correct the interpretation of the helmsman but pronounces *".. 335 .."* then the Master reiterates its order *".. 325 .."* and then the Helmsman confirms *".. 325 ..".*

The ship is at about 0.5 miles far from the coast.

The data show that VDR when the VRM circle "touches" the shore is going to be deactivated.

At 21 42 07 is ordered 330 and the helmsman answered correctly.

At 21 42 40 Master sends the 2nd Officer on the left wing, the speed is about 16 knots.

At 21 43 08 is ordered 335.

At 21 43 33 is ordered 340.

At 21 43 44 the speed is 15.9, the Master orders, always in English, *".. 350 ..",* the helmsman does not confirm properly (it repeats 340) and the order is confirmed again, specifying the side *"starboard"* and warning that otherwise would end up on the rocks (taken from video recordings of the VDR to 21 43 46 the bow is oriented to 327°)

The turn is still in progress when the ship is at 21:44:05 in position 42 ° 21'05 "N 010 ° 56 'E, with the bow in the direction of "Le Scole" at 0.3 miles and a speed of 16 knots.

The turning radius is such that the ship is located 0.5 miles SW of the planned route so much closer to the coast than planned.

From this moment the Master starts giving orders no more for bows but for rudder angles and in sequence gives:

- 21 44 11 Starboard 10 (ten degrees to starboard);

- 21 44 15 Starboard 20 (twenty degrees to starboard);

- 21 44 20 hard to starboard (rudder fully starboard);

- 21 44 36 mid ship (centre) - the bow is less than 150 meters from Scole rock, while the ship is off the planned course by more than 809 meters.;

- 21 44 43 port ten (ten degrees to the left), but the helmsman reaches only 5 degrees to the left;

- 21 44 45 port twenty (twenty degrees to the left) after this order the helmsman heads erroneously to starboard to correct himself and go alongside to port as requested by the Master, and then pulling again to the left as requested by the master, but spend about 8 seconds for the correction of the maneuver;

- 21 45 05 hard to port (rudder to the left) the helmsman runs correctly.

The Second Deck Officer from the left wing warns that the left side is gone aground, a second later it was heard a loud crash.

Appendix F. Event description of near miss at The Company

Recently prior the event described below, an incident occurred at The Company that can be related to the one discussed in the report. During an installation, old transmitters were reused and when cabling was connected, instructions were not complete. After a short circuit on one transmitter, it was found that the cable entry was sealed with thread tape. The tapes properties deteriorate and are due to that not allowed in hot and humid environments. One of the reasons why the tape was used was that The Company's installation instructions does not have any clear guidance for sealants. Among the corrective actions it was decided to revise the current instructions for installations so it was adapted to current standards.

October 2013

It is decided that the tubes, connecting a warm chemical process tank with pressure measurement equipment, shall be fully isolated. The decision is made by the provider of isolation and an isolation engineer at The Company. A result of the decision is that containers of the pressure monitors that previously have been uncovered is now covered. The event is initiated by that an environmental-project order removing and redo isolation in order to change cables. Cables are usually changed every ten years due to the hot and humid environment.

While considered being the correct instance for making the decision, the unit for maintenance does not consider the temperature limitation of the new cable. The new isolation was not discussed with any representative from the environmental-project.

The reason for the decision to cover the pressure monitor container is to decrease the heat radiated from the containers. It shall be commented that;

- The blueprints that the decision is based upon are not complete, they did not include a maximum temperature for the pressure monitors. The blueprints state a maximum temperature of $200°C$, however, this is for the connecting tubes and not the pressure monitors who have a maximum temperature of $150°C$.
- In the instructions for insolation, the pressure monitors are not included in the list of sensitive material.

It is from the complementary interview clear that there existed a decision path at the time that included risk assessment and that it was followed when the decision was made.

December 2013

Pressure monitors are stripped and removed for maintenance in the workshop.

December 2013

An installer suggests that shrink tubing shall be used to protect the new cable against a sharp edge, primarily during the installation. The installation leader forwards the issue since (s)he consider his/hers competence regarding what material is allowed to use insufficient. The issues regarding usage of shrink tubing is forwarded to the unit for equipment maintenance, who in turn consults the QA-officer. An expert of cables on

the maintenance unit (not the constructer) is consulted. All approves the usage of shrink tubing.

The usage of shrink tubing is not documented.

The unit for maintenance understood it as the shrinking tube would be on the cable isolation and that it then would not result in any errors although it was not certified for that environment. If the material would have degraded due to the high temperature, it would still have fulfilled the function of mechanical protection during installation. The unit for maintenance was during this time not aware that the temperature would be higher due to the full covering insulation. The same applied to the personnel on the cabling installation company who was asked but did not have any knowledge regarding the temperature. The instances approving the usage of shrinking tube are experts in the area and it is considered to be the right decision path.

The decision was taken under time pressure and without full understanding or discussion regarding how shrinking tubes usually are installed.

December 2013

Shrink tube is pre-mounted on cable prior installation in pressure monitor. The installation of cable follows instructions.

The installation instructions are not updated with the introduction of shrink tubing. This is due to the installation company's manager's absence of clear instructions for how such updates shall be conducted. Further on, the installers considered the shrink tubing to only have a protective function and that it did not affect the electric ability in any way.

December 2013

Review of pressure monitor installations are conducted without remarks. The shrinking tube is not noted during the review, however, it is not included in the review instructions to document installation details. There are two instructions that to some extent contradict each other; "…the installation company's manager can determine if a simpler deviation can be corrected without documenting it" and "Smaller deviations shall be marked in the installer's modification description."

February 2014

Circuit control conducted by the "Testing group". Despite that it is included in the checklist for the montage control of pressure monitors, no megging (insulation measure) was conducted. The reason for not performing the megging is that it is not "usually" performed on this type of equipment and that the instruction for how to perform the megging is hard to find. In the overall descriptions (OD) it is stated which controls that shall be conducted and who should do it. In the OD, only the testing of circuit control was included for the testing group. The testing group did not consider the installation audit instructions when conducting their work.

February 2014

Insulation of pressure monitors. Work with insulation is conducted according to instructions. Audit of work is conducted by insulation contractor and the maintenance unit.

24th March 2014

The process is restarted after a quick stop. Authorization for restarting the process is given.

11th April 2014

Two ground faults are detected. Ground fault at pressure monitor A1 at 01.31), and pressure monitor A2 at 19.34.

12th April 2014

Operation Decision Making meeting, due to ground fault A1 and A2. Decisions made during the meeting: "Stop process and trouble shoot A1 and A2 and with that as ground, decide on inspection of other monitors".

12th April 2014

Process stopped, process putted in standby.

13th April 2014

The unit for maintenance inspects the A2 pressure monitor. The ground fault disappear when touching the cable, giving the impression that the cable lug have metallic contact with the inner part of the junction box, which is seen as explanation to the ground fault. The inspection is conducted during poor circumstances, with high temperature and little space.

13th April 2014

Informal meeting between operations management and maintenance. Maintenance is thereafter ordered to inspect the other pressure monitor. Production management and maintenance decide to conduct megging of all pressure monitors in order to rule out problem with the others, and to discuss the problem in a safety assessment meeting.

13th April 2014

Further inspections of pressure monitor A1 is conducted by the unit for maintenance.

13th April 2014

During the safety assessment meeting, it is concluded that faulty montage of cable lug is the reason to the ground faults. During the meeting, the installation instructions are present. It is during the meeting noted that no megging is performed during the installation "which should have been conducted in order to evaluate the work". It is concluded that "the monitors function will work correct even in case of ground fault, why the effect on the process safety is small" and "if a ground fault occur, an alarm will go of but the function will be unaffected".

If the “testing group” that conducted the circuit testing would have been involved in the meeting, the theory of faulty installation could have been abandoned since their testing would have indicated ground fault directly after the installation.

The meeting concludes that “If the megging and inspection of monitors is conducted without any remarks alternatively that errors are fixed if needed, the groups opinion is that the troubleshooting/control is broad and thorough enough. An important argument is that all monitors that can be suffering from the problem will be examined and fixed if needed. The group believes that the process can be restarted after conducted control/fix”.

13th April 2014

All ten pressure monitors are megged by the maintenance unit with varying result. According to the table where the values are presented, 100MΩ is min. value, the measures varies between 0.08 MΩ and <2000 MΩ. Four of the monitors show a value below the min. value, however, there is only one of the four that are commented and discussed on the upcoming operational meeting (OM) (meeting A).

13th April 2014

On OM A the safety assessment meeting is discussed. OM comment that the ground fault on A1 is due to similar breaches in montage of a cable lug. The equipment maintenance unit report that all monitors are megged with approved result. A noted remark during megging is made, it is considered to not affect the operational readiness. Operational management agrees with the decisions made during the safety assessment meeting.

Also “Process operational report result after corrective actions by ground fault in pressure monitors in system A” is presented and it is presented that affected pressure monitors are verified to be operational ready in conjunction with testing and that performed controls will not have affected that verification. Safety is considered unaffected since the function is found error free.

Operation management agrees with the operational reports position in the issue. The meeting concluded that an evaluation and assessment according to deviation matrix shall be conducted by maintenance unit due to the poorly installed cable lugs.

Following was discussed during the meeting;

- The large variation of values from the megging was due to that not all cable was changed to pressure monitors.
- The short operating time might have affected the monitors through vibrations and temperature which could be the cause to why the ground fault occurred when it did.

The meeting also discussed that the ground fault did not affect the site.

13th April 2014

A basic and a final safety audit of restarting the process was conducted, neither of them has any objection to restart the process.

The basic audit discusses "Is the required documentation updated and presented (instructions, technical safety instructions) as a response to plant modifications or analyses?" and "Are possible plant modifications or maintenance actions evaluated /taken care of?" (Both of these marked as "Not applicable"). The final audit is based on evaluation and judgment of documentation and that the QA unit has been following instructions through participating in safety assessment meetings and OM A.

13th April 2014

The process is restarted.

14th April 2014

At 06.12, a ground fault alarm goes off, it is located to the pressure monitor A3.

14th April 2014

The ground fault result in an understanding that the cause is not the poorly montaged cable lugs. During a discussing between operators and the maintenance unit, it is discussed that marks was spotted during inspection of pressure guards that might have been due to heat and that it might have affected the ground fault. The shrinking tube montage is discussed.

14th April 2014

During a safety assessment meeting, two new interacting causes to the ground fault are discussed: "When the ground fault occurred on A3 it was found that a probable cause was conduction through the shrinking tube that was used during the montage. During the previous process review, insulation has to some extent been changed in area A, resulting in that some pressure monitors have experienced higher temperature than earlier."

The meeting's judgment of the monitors function is that it will work correctly even in case of ground fault and that the risk for short circuits is low.

During the meeting is "Technical evaluation of temperature sensitivity of cable to pressure monitors to the process" presented. From the evaluation it is concluded that the pressure monitor and the cable are qualified for $200°C$ and that the current temperature is approximately $240°C$, resulting in a much shorter operating time for the materials. The lifetime of the equipment is estimated to at least one year during the current circumstances. The increased temperature probably results in a decreased isolation of the shrinking tube to a level below the ground fault level and may cause ground fault. The meeting conclude that "it is very unlikely that two ground faults that might affect the function of the pressure monitors. This is based on that a ground fault is detected and isolated from current rail by reporting it within an hour after occurrence".

It is concluded that the design of the process pressure monitoring is robust since all pressure monitors, except C4, has diversification through dP transmitters. If all pressure

switches are experiencing error, there are hence diversified pressure measures that trigger the process in C3 and C2.

It is decided that "there is a respite to conduct operations provided that follow-ups of the status of the cables occurs through continuous megging". This follow-up shall be described in a fixed program, developed before April 17th and shall include acceptance criteria for when degradation of isolation shall be acted upon. The program shall be formulated in such way that the risk for introduction of errors is minimized.

"The group believes that it must be concluded that it is the shrinking tube that has degraded to that extent that it has become conductive and hence caused the ground fault. Prior the next process review, the mechanical strength of the mantel should be evaluated". With the corrective actions discussed, the meeting considers the process ready for operation.

It is further commented that the temperature of the pressure monitors should be decreased as soon as possible in order to reach correct operating conditions.

15th –18th April 2014

Temperature test of shrinking tube. In order to test the isolation capacity of high temperature cables with shrinking tube, test were performed. The test was performed by the qualification unit with representative from the installation company and was documented. The conclusion of the test was that high temperature cable with shrinking tube gest a decreased isolation capacity at higher temperatures, higher temperature result in poorer results. Though, neither test 1 nor 2 shows such low isolation resistance that ground fault would occur. This implies that the test conditions is not fully comparable with the conditions for the pressure monitors, e.g. how the shrinking tube have been place over a cable lug and squeezed in the pressure monitor container.

15th April 2014

At a new OM (meeting B), the previous safety assessment meeting is presented. After that, two questions are discussed a) the consequences of double ground faults and b) if it really is the shrinking tube that have caused the ground faults and if not, if it could result in ground fault. The answer to b) is "Yes, from the process point of view it does not matter what caused the ground fault".

Production management agrees with the safety evaluation and three corrective actions are documented:

- Protocol from audits from the environmental-project's installation and from the isolation work shall be controlled.
- A schematic diagram of measuring circuit and explanation regarding the ground fault issue shall be developed and forwarded to a safety assessment meeting.
- The process operators shall be told to be observant of floating measurement points.

15th April 2014

Production manager decides that if ground fault occurs, the manager of C3 shall be informed. There-after, the process shall be shut down unless the manager of C3 in agreement with shift manager on duty says so.

15th April 2014

An alarm of another ground fault comes in in the afternoon. It is localized to pressure monitor A4.

15th April 2014

Right after the ground fault, it is decided to stop the process.

The complementary interview states that the actions taken after the forth ground fault were to redo the installation that included the shrinking tube and update the installation instructions for the pressure monitors.