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Software safety issues in the maritime industry, and challenges related to human computer interfaces. Theoretical background and results of a survey among equipment suppliers, yards and classification societies in four European countries.

Stina Ramdahl Turkerud

Master of Science in Informatics
Submission date: May 2007
Supervisor: Torbjørn Skramstad, IDI

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Preface

This report contains my master thesis “Software safety issues in the maritime industry, and challenges related to human computer interfaces. Theoretical background and results of a survey among equipment suppliers, yards and classification societies in four European countries”. The work has been carried out from August of 2006 until end of May 2007 at the Department of Computer and Information Science (IDI), Norwegian University of Science and Technology (NTNU). The thesis is submitted in partial fulfilment of the degree Master of Science in Informatics.

I would like to thank my supervisor Torbjørn Skramstad at IDI for all of his counsel and advice. I would also like to thank Andreas Aas, also from IDI and Arve Lepsøe, from DNV for their help.

Oslo, May 29th, 2007

Stina Ramdahl Turkerud.

Abstract

This thesis concerns the safety in user interfaces. In particular it concerns the user interfaces in systems in which safety is critical. I have studied such systems in the maritime industry, where we for instance may find them on the bridges of ships. Computer systems get more and more important in the daily routines of humans, and it is important that this does not go unnoticed. Designers of computer systems need to take human factors into consideration when designing their systems. These considerations might be especially important in complex systems, as these are often safety critical. The bridges on ships are likely to include complex systems for the operator to handle, as they often involve multiple screens, or other factors that increase the complexity of a system. Such factors might include being able to pay attention to several incidents at once. When dealing with complex systems, it is important that the operator knows how to handle the system, and also how to react when an incident occurs. These are factors that need to be considered by the designer when making the system and theories on how to do this are described in the thesis. I have also described standards which consider this, like the ISO 11064 standard, or the Atomos regulation and the ISO 17894 which considers this for the maritime industry in particular.

Parts of the industry have made an effort to develop tools to be used to improve the safety. I have studied some of these efforts and presented them in the thesis. Furthermore, I have developed a survey to study how the individual members and different parts of the industry feel and behave towards safety. The survey gave an insight into reality of how safety is being handled in the industry as a whole. In particular it pointed to the main problem of the maritime industry, that the industry is very heterogeneous, and also that the different parts of the industry are in competition with each other. Most of the respondents had not heard about the Atomos regulation or the ISO 17894 standards, efforts that could have been used as a tool to improve the level of safety. The questionnaire also showed that while most of the respondents are satisfied with the level of safety in their organization, they are not satisfied with the level of safety in the overall industry.

The thesis consists of six parts. Part I deals with the introduction and general theory from research methods and psychology. Part II deals with usability and related standards. These include ISO 11064, theory on usability and a description of an accident due to poorly designed user interface. Part III describes relevant background from the maritime industry, which involves the ISO 17894 standard, the Atomos regulation and e-navigation, an example of a newly made effort. Part IV gives a description of the development of my questionnaire, and also provides the results and conclusions made from them. Part V provides the conclusions and suggestions for future work, while part VI contains appendices.

TABLE OF CONTENTS:

PART I: GENERAL THEORY AND INTRODUCTION

Chapter 1 Introduction

User interface is the component of a computer system that the operator uses to interact with the computer – the screen display, keyboard, mouse, touch controls etc. [1]

When humans are given the job of operating computer systems, it is important that they are able to understand them. The most important means of cooperation with a system, from the human operator's point of view, is probably the user interface. If you want the operator to be able to handle the system in a correct and efficient manner, the system developer needs to focus on making the user interface understandable. If the operator is dealing with a safety critical system, this issue becomes even more important. These are subjects that I am dealing with in my thesis.

In an effort to narrow this broad topic, I have focused on the maritime industry. The reason for this is that my advisor works at DNV. I chose to write about the user interface and how the users interact with it, because it is a topic which I have great interest of. I am majoring in HCI (Human Computer Interaction) and systems development, and my thesis deals with the HCI part in particular. In my education I have also studied subjects related to psychology and pedagogy, so I got to use some of my experience within these fields as well. In particular I have a great interest in how the experienced and inexperienced user deals with the systems that practitioners have developed.

1.1 My research questions

After thinking about it for a while, I came up with the specific research questions that I wanted answered. This process included reading, and talking to my advisor about what we wanted to get as a result from the thesis. The research questions are:

1. What standards and regulations are available for the maritime industry to use when developing safety critical systems?
2. How does the maritime industry deal with the safety issue?
3. Do they take standards and propositions regarding the development of user interfaces and use them in practice? If yes, which standards and regulations are they familiar with?

When trying to find answers to these questions I performed a literature study, in order to familiarize myself with the industry and also the efforts already made. Seeing that I am first and foremost a computer science student, I had no experience with a lot of the issues that the maritime industry deals with. This fact made the process of reading relevant literature even more important. With help from my advisor I found a lot of literature that had to be examined and read. The most important findings, mainly standards and regulations are presented in the thesis. ISO 11064 is a standard that concerns the design of control centers, and deals with many of the issues I wanted to study. The standard is presented in detail in my thesis, so is the ISO 17894 standard. This standard is a result of the ATOMOS proposition, which deals with safety handling in the shipping industry. Among one of the issues presented is how to design user interfaces with a high level of safety. Both ATOMOS and ISO 17984 are presented in my thesis. I have also taken a closer look at the psychological issue, more specifically how designers can learn about the human mind and use this information to make better user interfaces. The most relevant issues that designers need to consider are presented in the Psychology chapter of the thesis. There are some general rules on how to develop the user interface, I have chosen to present the ones I find most important in the Psychology chapter. These rules are there to help the design in the development of an efficient user interface. I have also included a chapter about usability, that give pointers and rules from a computer science point of view.

When I had a sufficient level of understanding about the maritime industry and the relevant literature, it was time to try to get more information from the participants in the industry themselves. This was done with the use of a self completion questionnaire, which was sent out via e-mail. The results from the initial questionnaire did not reveal as much about the user interface as anticipated. The reason is probably that the respondents had much less knowledge about official efforts to improve the level of safety, than I thought. As a result of this, I made a follow-up questionnaire which mainly focused on the user interface. How I made the questionnaires and why I made the choices that I did is presented in detail in the thesis.

1.2 Thesis outline

I have chosen to present my research method first, because this laid the foundation for the rest of the thesis. I then present the relevant theories, methods and standards. This is done to give proper background information, before presenting the two questionnaires and their respective results. I conclude with an overall conclusion and a chapter about future work.

The thesis is organized as follows:

PART I: GENERAL THEORY AND INTRODUCTION

- Chapter 1 – Introduction
- Chapter 2 – Research method.

  Deals with the theory of the qualitative method, and theories on how to make a good questionnaire. It also explains how I have used the theories.
- Chapter 3 – Relevant theories from psychology.

  Describes theories from psychology that are relevant when designing systems that humans are to use or operate.

PART II: USABILITY AND RELATED STANDARDS

- Chapter 4 – Usability.

Describes usability theories that are relevant when designing systems for humans. This is relevant to my thesis because it deals with issues that needs to be considered when designing "safe" user interfaces.

- Chapter 5 – User interface standards.

Describes the standards that are available in short, goes further into the ISO 11064 standard, as well as the DNV rules for Classification. This is an example of a standard that might be user to develop better control centers, and is therefore a natural part of the thesis.

- Chapter 6 – Accidents due to poorly designed user interfaces.

Presents the Three Mile Island accident, which is a frequently used example of an accident, due to a poorly designed interface. The chapter explains why it is important to learn from this type of accident.

PART III: RELEVANT BACKGROUND FROM THE MARITIME INDUSTRY

- Chapter 7 – Atomos IV and the ISO 17894 standard.

Presents Atomos IV and the ISO 17894 standard in detail. As the ISO 17894 standard is based on the Atomos IV proposition, it is natural to keep them in one chapter. They are relevant to my thesis because they are examples of effort made by the maritime industry to increase the level of safety. They are also relevant because they provide a tool for the industry to use.

- Chapter 8 – E-navigation.

Presents the e-navigation proposal.

PART IV: THE SURVEY AND QUESTIONNAIRE

- Chapter 9 – The work with the questionnaire.

This chapter explains how the theory from chapter 2 was used in practice.

- Chapter 10 – The initial questionnaire.

Presents analysis and discussion of the result and a conclusion.

- Chapter 11 – The follow-questionnaire.

Presents analysis and discussion of the result and a conclusion. The follow-up questionnaire provides a deeper insight into the specific user interface issues.

PART V: CONCLUSION AND FUTURE WORK

- Chapter 12 – Overall conclusion.
- Chapter 13 – Future work.

PART VI: APPENDICES

Chapter 2 Research method

In this chapter I will present the theory of qualitative methods. I will also compare qualitative methods with quantitative methods. Furthermore I will explain the theory of making a good questionnaire, and how I used these theories in practice. Finally, I will discuss how the results of the questionnaire were analyzed and discussed.

In my thesis I have chosen to use a qualitative approach. The most important part of my thesis is the questionnaire, and the analysis and discussion of the results. The basis for the development of the questionnaire is literature studies of relevant subjects.

2.1 Qualitative studies

The distinctive character of a qualitative study is that its goal is to understand the reality as it is perceived by people that are being studied. In my case I want to understand how the people in the maritime industry perceive the level of safety in their industry.

Qualitative studies may take several forms. Examples are:

- Interviews with the studied parties (i.e. the persons being studied, persons representing the issue studied).
- Observing how the studied parties interact (i.e. how people within a group interact).
- Analysis of available documents relevant to the research.

2.1.1 Common features of all qualitative approaches:

The data that the researcher is focusing on is represented by text, rather than numbers. The researcher is in contact with the groups or people being researched.

2.1.2 Qualitative studies and quantitative studies

Unlike what is the case with quantitative studies, there are no fixed or single set of conventions when dealing with qualitative data. [2]

The qualitative method is characterized by words and text. The researcher deals with questions types like how, why and what. The researcher typically deals with unexplored phenomenon, and builds his/her theory from empirical data, small samples or in-depth studies. Quantitative methods on the other hand deals with numbers and counting. How many is a type of question that might be asked. The researcher starts with a theory, which is developed in to a hypothesis, which is tested using data. Data takes the form of statistical calculations, large samples. The researcher might generalize to the larger population.

2.2 Surveys and questionnaires

Most surveys are carried out with the use of a questionnaire. There are three types of questionnaires to choose from [2]:

- A self-completion type of questionnaire: With this type of questionnaire the respondents fill in the answers by themselves. The questionnaires are sent out via mail or e-mail, this is to permit for the questionnaire to reach large groups of people with relatively little effort.
- Face-to-face interview: With this type of questionnaire an interviewer asks the respondent the questions of the questionnaire. The interviewer completes the questionnaire on behalf of the respondent.
- Telephone interview: this works in much the same way as the face-to-face interview, only that in this type pf questionnaire the interviewer contacts the respondent via phone.

When dealing with the respondents, the researcher usually wants response from individuals, although some individuals might be responding on behalf of a group or an organization.

The problem with a self-completion type of survey is the time it takes to collect data, if the recipients do not respond to the questionnaire. A substantial amount of time is taken up because it is necessary to send out reminders and repeat the questionnaires if the respondents do not respond. The survey that provides the fastest data collection is the telephone interviews. However, it is important noting that this relies on the availability of the respondents. If they are repeatedly unable to answer the phone, this form of questionnaire will also take up a lot of time.

As with all methods of study, questionnaires have both advantages and disadvantages. The advantages of a questionnaire, especially a postal or self-administrated type of questionnaire, is that it is often the only, or indeed the easiest, way of retrieving information from a large set of people. Also, they allow for anonymity. The anonymity might encourage frankness when answering sensitive questions. More general advantages to surveys and questionnaires is their ability to provide a simple and straightforward way for the researcher to study attitudes, beliefs, values and motives of the respondents. However, there are disadvantages to using surveys and questionnaires as well. General disadvantages that apply to all types of questionnaires and surveys are that the data gathered are affected by the characteristics of the respondents, i.e. their answers are limited to their memory, knowledge, experience, motivation, personality and also the time they have available to answering the questionnaire. It is also important to have the possibility of the answers not being accurate in mind when examining them. Respondents will not necessarily report their beliefs or attitudes accurately, they might chose to answer in a way that makes themselves look good. Disadvantages specific to the postal or self-administered surveys include the problem that the respondents might not take it seriously, as it takes place in a less serious frame. Also, self-administered surveys and questionnaires generally have a low response rate. In addition to this, it might become a problem if there are ambiguities, or misunderstandings related to filling out the questionnaire, and this might not get detected when it is a postal or self-administered survey. Surveys work best if the questions are standardized and there is a high probability that they mean the same thing to all the respondents.

2.3 The design of a survey and questionnaire

2.3.1 The actual look of the questionnaire

There has been a lot of work around the subject of good pedagogy for a questionnaire, and I am including a few points that I found helpful when making my questionnaire. This mainly concerns the making of the questionnaire with questions such as which typeface should one use, how should the questions be numbered and such initial concerns.

The simplest rule when is comes to the typeface in the questionnaire is that it should be sufficiently large and clear, to make it easy for people to read. The authors of the book [3] suggest 12 point type for the questions. You should also number the questions, in order to avoid confusion. An example of when this is useful is when the respondent inadvertently has skipped a question, with the numbering it is simple to alert someone of this mistake. When dealing with the actual questions an important point is that a short question should never follow a long question at the bottom of a page. The reason why this is important is that such a question is frequently omitted in error. In general; care should be taken with how the questions are placed.

Following advice like these are especially important in self-administered questionnaires as the answering of these relies completely on the respondent. The general rule for self-administered questionnaires is that they should look as easy as possible to the respondent, the questionnaire should also give the appearance of being professionally designed. One should also allow for white space on the pages included in the questionnaire, this makes it look easier to fill out and generally results in higher cooperation and fewer errors made by the respondent. However, it is important that you provide enough space for the respondent to answer.

In addition, the researcher should also include a part where he thanks the respondents for their efforts, and the use of their time.

2.3.2 Behind the questions, the theory of the design and planning of the questions:

In the initial phase of a questionnaire making, it is important to realize that the questions should not be made by the researcher sitting down and making up some interesting things to ask. Rather, the questions should be designed in a way that helps the researcher to achieve the goals of his/her research. The most important thing to bear in mind is that the questions should help answer the underlying research questions. When this is done, it is important that the questions are interpreted in the same way by the respondent as the researcher. The questions should also be written in a way so that the respondents understand what the researcher wants from them, the questions should also make the respondent wanting to answer them. All of this should be done while remaining faithful to the research task. It is important that the researcher gets the wording of the questions right.

When designing self-completion questionnaires, one should cut down open-ended questions to a minimum, however, if one deals with a small number of respondents, this is not necessary. The reason why one should cut down on the open-ended questions is because they require a lot of time, due to the fact that they need more analysis from the researcher. If there are a small amount of recipients these is not a problem, as it will take less time to go through the answers.

There are some factors that a researcher may use to secure a good response rate to a postal questionnaire. The appearance of the questionnaire is very important, it should ‘invite’ the respondents to answer. One way to do this is by making it look simple to fill in. This is done by having plenty of space for questions and answers. The instructions to how it is filled in should be clear, with easy-to-understand instructions. The arranging of the questions is also of importance, the researcher should take care that the respondents read questions that make them feel unfit to answer the questionnaire early on. The initial questions should be simple and interesting, in order to catch the respondent's interest. This should also be the case for the last questions, this will encourage the respondent to return the questionnaire.

2.4 Summary

In this chapter I have described my research method. I used a qualitative approach. The goal of this type of research is to understand the reality as it is perceived by the people being studied. I have studied members of the maritime industry. In addition I have described theories concerning the making and look of surveys and questionnaires.

Chapter 3 Relevant theories from psychology

In order to be able to develop a user-friendly user interface one needs to take time to consider the psychological issues that influences the user when dealing with our program. It is with this in mind that I have decided to include a chapter that deals with the basics of psychology, more specific, the topics that are most relevant to the system developer.

3.1 Relevant psychological background

Psychology is defined as "the scientific study of behavior and the mental processes" [5] The field of psychology deals with different questions that cover most parts of human life. This could be questions like why even identical twins separated at birth have some of the same behavioral patterns, or how can we design a user interface or program that is well suited to deal with human interaction? As with other sciences how you chose to interpret the answers you get will be colored by which theories you consciously or unconsciously support. Psychology can be divided into several sub-fields. Examples of such sub-fields are cognitive psychology, personality psychology, social psychology or biological psychology. Traditionally the system developer deals with the cognitive psychology. However there are several sub-fields of psychology that could be relevant to the system developer, this includes areas such as social psychology and personality psychology.

3.1.1 Social psychology

Social psychology is the study of how people's thoughts, feelings and behaviors are influenced by the actual or perceived presence of others, this presence could also be implied. The psychologist who deals with this topic are engaging in the social processes, as described above. The basis of social psychology is an observation that not only is the persons behavior dependant of his or hers attributes, but it is also dependant on the situation that he or she is in. The most important point for system developers is that all individuals have a unique collection of personal attributes, and they bring this collection into every situation they may find themselves in. This set of attributes control how each individual handle the situation. Each situation also has a set of attributes that differ between different situations and affect the individual in different ways, this is why we act differently in different situations, although our attributes may stay the same. What this actually means is that we bring our personal interpretations into a situation, and interpret it accordingly. However, when looking at other peoples actions we tend to forget how important the situation is, and only leave it to personal characteristics when we judge them. An example of this is if we see a person behaving aggressively, we tend to judge this person to be an aggressive person without taking into consideration that this individual may have been in a situation where most people would behave aggressive. This tendency is called internal attribution.

3.1.2 The Social facilitation effect

In 1898 Norman Triplett [6] noticed that the presence of others affected how we perform, this is called the social facilitation effect. There are two sides to this story, one about how this can affect of positively and also how it may affect us in a negative way. The positive way mostly concerns athletes. Norman Triplett discovered that cyclists performed better when they cycled with others than they did when cycling on their own only competing with the clock. Later other psychologists discovered that the same happened when a passive spectator was present. This lead to more experiments being performed, in which they realized that this discovery was only valid for simple, thoroughly rehearsed actions or responses. If the actions one is supposed to perform are complex and there is no time to rehearse the effect is the opposite. However, and this is important to the system developer, the fact that we don not perform equally good when spectators watch us do complex tasks might be caused by the human dislike in being watched, evaluated or monitored. This is especially true if it is a superior who is doing the monitoring, watching or evaluation, and less true if it is done by people "lower" than us in the social or promotional ladder. System developers need to take this into consideration when developing the system, and especially the control room. If we design a room with glass surrounding, which the superiors can use to monitor the workers, this might pose a problem, and affect the performance of the workers. This fact has to be seen in relation to our cultural upbringing, we are from we are children taught to impress our superior and avoid letting them down. This need to impress our superiors might work the opposite way in safety critical system, as it might lead us to skip important procedures or sequences in order to impress the superiors with our quickness. Also the feeling of being watched or monitored leads to stress related feelings in many individuals.

3.1.3 Cognitive psychology

This area of psychology studies how the brain processes information. This includes the study of internal mental processes like problem solving, memory and language. Its foundations are in Gestalt psychology which will be dealt with later in this chapter. This area is especially important for developers of safety-critical systems, as this area delves into how people act and think. When developing a safety-critical system one needs to take into consideration these issues, and in particular how people deal with stressed situations and how we can try to prevent potential human errors.

Important issues that are being dealt with in cognitive psychology are perception, learning and memory, retrieval and thinking. This also serves a sketch for the different stages that information goes through in the brain. When information comes through the sense organs to the brain, they go through a perception phase in which the content of what the sense organs brought is being analyzed. Even at this stage the brain tries to extract information from the input in order to understand what is happening. From the perception phase the input moves on to the learning and memory, in this phase the brain stores the input, which then turns into a memory. This memory could then be subject to retrieval at a later stage. This retrieval may be done in order to make sense of a new situation or problem, or we may retrieve it at a later stage in order to continue to work on it. In turn this means that thinking is a mere retrieval of old memories. Below is a figure explaining the steps, however it is important to notice that the best way to view it is with the phases overlapping. Also, the cognitive processes are more complex than described here.

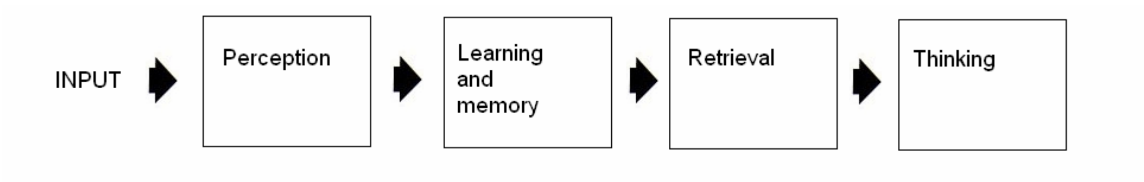

Figure 3-1: Information handling. A coarse sketch of how human adapt information.

3.1.4 Thinking

Thinking is a higher cognitive function and the analysis of thinking is a part of cognitive psychology. Thinking is a mental process in which humans to model the world, in order to deal effectively with it according to their plans, goals, ends and desires. In order to think we need to manipulate the information we already have or recently gained, this leads us to form concepts which in turn makes us able to involve us in problem solving, reasoning and make decisions. An important common feature of all of these activities is that they are under the users' control, and our actions can be performed in theory rather than in practice. And these activities will help us in everyday situations, but in particular, they will help us when dealing with special circumstances. If in situations that deal with special circumstances we will have to be able to define where the problem lies, gather and test theories and hypothesis and test these, mostly in theory. Eventually we will have to reach a decision regarding what to do, and this decision is especially important in systems that are safety-critical. When dealing with safety-critical systems it is important that you are able to deal with all kinds if situations, both major and minor, in a swift and precise manner. It is also important that the system does not add to the stress by behaving erratic. This might lead to the user taking poor or bad decisions and in turn, the damage might get more serious than what was necessary. An instrument that the designers can use in order to achieve this is the use of icons and equipment that is already familiar to the user. This is useful because the user has one less thing to learn or familiarize him- or herself with when taking the system in use. If unnecessary ways of use is added this may lead to a confusing system that is difficult to use.

3.1.5 Perception

This is the process of acquiring, interpreting, selecting and organizing sensory information. We gather information about the world and interact with it through our actions. Perceptual information is vital for action. Perceptual deficits may lead to profound deficits in action. The most important perceptual information when dealing with computers is the information we get through our eyes, but also our ears.

What happens when we get information through our visual system is that the information gets sent to the brain, more specific to an area called the thalamus. The thalamus reports this information on to the visual part of the brain. In fact all the sensory organs gets sent to the thalamus, with the exception of smell. It is believed that this part of the brain plays a key part in getting us to focus on stimulus.

As I have mentioned earlier in this thesis many cognitive psychologists believe that, as we move about the world, we create our own model of it, and how it works. This does not mean that we do not sense the objective world, outside our model, but we map it to our fit in our model. However, as we acquire more information that does not fit in our mental model we have to change our existing model.

3.2 Gestalt psychology

Gestalt psychology is the theory of mind ad brain that proposes that the operational principle of the brain is holistic, parallel, and analog, with self-organizing tendencies. [6] The word gestalt itself actually means unified whole. Gestalt theory was founded by the German philosopher Max Wertheimer, Wolfgang Kohler and Kurt Koffka. According to gestalt theory the whole is different than the sum of its parts. When talking about a Gestalt effect, we are referring to the human ability to visually recognize figures and whole forms, rather than to see them as collections of simple lines and curves. All humans seek full forms rather than incomplete images. One way that gestalt theory can be used in computer science is as a guide to placing etc. radio buttons in the user interface.

According to several Gestalt psychologists and researchers humans have a tendency to group visual stimuli according to certain grouping principles. They are known as the Gestalt principles. There are five such principles: proximity, similarity, continuation, closure, symmetry and the law of pragnanz. However, before I explain them, it is important to notice that although they are called laws, this is not the best word. A better word would perhaps be principles of perceptual organization. However, I have chosen to call them laws, as this is the way they are referred to in the literature. Also, these laws serve as heuristics to humans, by this I mean that they serve as shortcuts for solving problems.

3.2.1 The law of pragnanz

This is the most fundamental rule of gestalt. This law says that we try to perceive images with as good a gestalt as possible. What this actually means is that we try to perceive images in a way that is regular, orderly, simplistic or symmetrical. However, there are other ways to perceive images as well. We try to see elements in a image in a way that makes it as simple as possible.

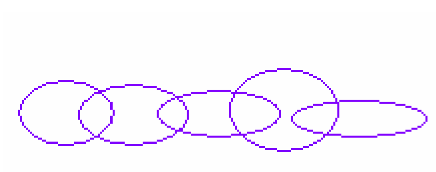

Figure 3-2 The law of pragnanz

In this figure we would rather chose to view the image as a series of circles than as many more complicated shapes.

3.2.2 The law of proximity

This rule is applied whenever we see elements that are placed together, in proximity, of each other. When humans see such elements we tend to recognize them as being a group.

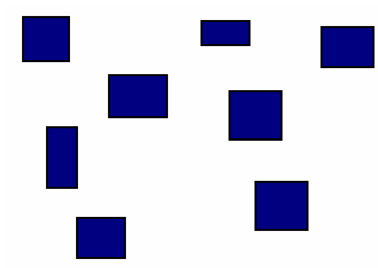

Figure 3-3 The law of proximity

These elements are presented far enough apart for us not to perceive them as a group. Rather, we view them as separate shapes.

However, the elements in the next figure are places close enough together for us to instinctively and perhaps subconsciously group them together.

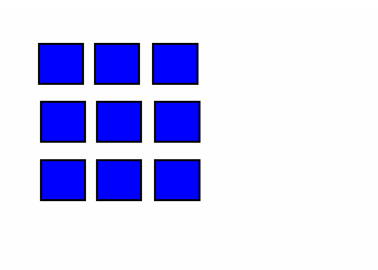

Figure 2-4 The law of proximity

3.2.3 The law of similarity

We apply the similarity principle when the elements visually look the same, or look similar to one another. When we think that they look the same or are similar we perceive them as a group or a pattern.

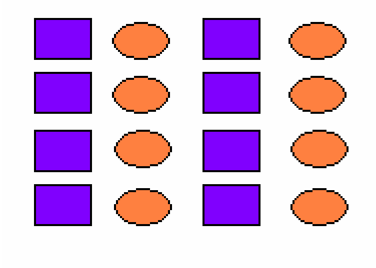

Figure 2-5 The law of similarity

This figure describes the law of similarity, as most people would see vertical lines of squares and circles when faced with this drawing. However, how we perceive this similarity is depending on the form, color, size and even brightness of the element. When dealing with similarity an interesting phenomena occurs if one of the elements are dissimilar to the other, this element becomes a focal point of the image. This is called an anomaly.

Figure 2-6 The law of similarity

3.2.4 The law of continuation

The law of continuation says something about how we as humans perceive visual images as continuous connections. We even continue a pattern after it stops. In particular the law of continuation holds that elements that are connected through straight or curving lines are seen in a way that follows the smoothest path. We perceive it this way, rather than seeing them as separate lines or angles. If there is a line, it is seen as belonging together. The actual continuation occurs when the eye is compelled to move through one object, and then to continue on to the next.

Figure 2-7 The law of continuation

What is meant by continuation in this picture is that a human eye will naturally follow the smooth line runs through the picture. In this case this is a smooth curve that leads us directly to the maple leaf at the end of the curve.

3.2.5 The law of closure

The law of closure occurs whenever a line is not completely enclosed. If enough of it is present we instinctively perceive it as a whole. In other words, it enough of the space is present we perceive it as a whole by filling in the missing information. We also tend to ignore gaps in order to create familiar figures or images. Sometimes we go as far as ignoring contradictory information in order to group things that seem to complete some entity together.

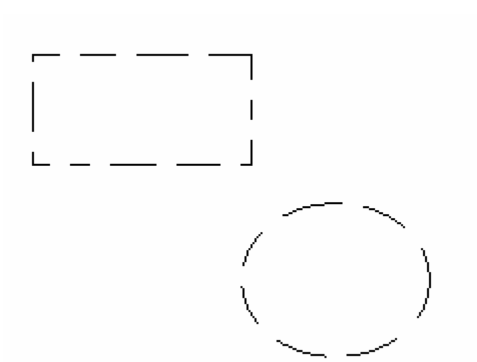

Figure 2-8 The law of closure

Although the lines in this figure are complete, we still perceive the images as lines making a rectangle and a circle.

3.3 Human memory

Cognitive psychologist divide memory into three categories, these are working memory, sensory memory and long term memory. The memory process consists of three stages, as described in figure 2-9.

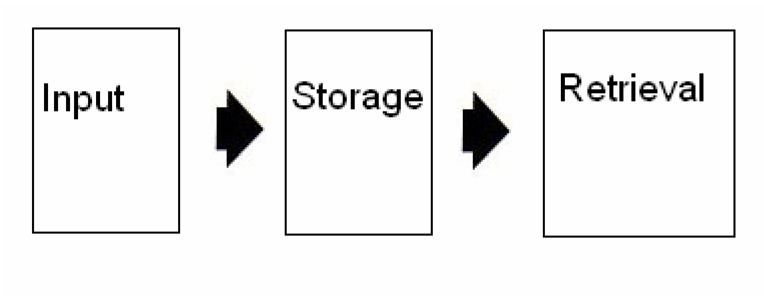

Figure 2-9 The memory process. From Groome [6]

The way that the memory in a computer works is similar to this, an example is how a file is stored on the disk. One needs to separate between the stages, as each stage needs to be completed before the next one can start. If this is not done we might not be able to retrieve the memory at a later stage. The three categories of memory can be seen in figure 2-10.

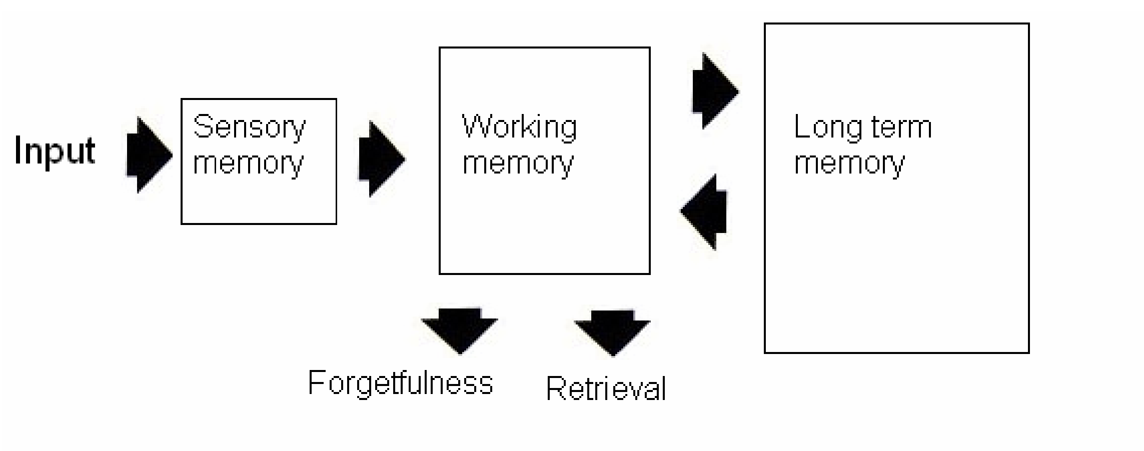

Figure 2-10 Multistore model. Atkinsons and Shiffrins multistore model. From Groome [6]

Many would recognize working memory as what we used to call short term memory, however, researchers recently revealed that this type of memory perform many other functions as well. Working memory is now considered to be where humans perform conscious thought processes and that the short term memory is a part of the working memory. When we have this description in mind it becomes clear that much of the work a user does on a system, i.e the user interface is being handled by the working memory. The problem related to the working memory is its limitations in capacity. The most accepted theory on the capacity of the working memory was suggested by Miller [7]. His suggestion was that we are able to remember seven plus/minus two, what this actually means is that the capacity of the working memory is limited to an average of seven chunks, plus/minus two. What is meant by chunks is that one unrelated element takes up one chunk, while a series of related element also takes up one chunk. A good way to explain what this actually means in practice is by taking a look at how we are able to remember numbers. If we are told to remember a series of, to us, totally unrelated numbers, like:

3 8 1 6 9 3 4 2 8 1 6 5 9 8

it will prove difficult for us, as it more than exceeds the magic seven plus/minus two rule. However, if we were to see this numbers little differently, perhaps like this:

381 6934 281 65 98

we are more likely to remember these number when we no longer see them. This is because fewer chunks would be taken in order to remember them. The first series of numbers had 14 chunks while the last one only took up five chunks in the working memory. The retrieval from the working memory is very fast, however the memory decay is also very fast, about 20 seconds.

Long term memory is where we store memories that are retained over time. The memory decay in the long time memory is very slow, in fact some researchers claim that we do not actually forget, or lose a memory, we just aren't able to find them. The retrieval method of the long term memory is that of self terminating parallel search. What is meant by this is that all the information available is looked at, at the same time, and is the search is terminated when the wanted information is found.

It is important to notice that there are several theories regarding the long term memory, some think that every operation is performed by the long term memory, and that working memory and sensory memory is a part of the working memory rather than distinct from it. The other theory is, like previously mentioned, that the memory consists of the three parts, working, long term and sensory memory.

Sensory memory is the memory that processes input from the senses, as the name suggests. By senses we mean eyes, ears, nose, tongue and touch. The sensory has a large capacity, but the shortest duration lasts only 250 milliseconds.

Now, one might wonder what all this information does in a thesis in computer science, however, when designing the user interface one should not ignore the importance of these issues. Although it should be used while reflecting one why, not used just so the designer can say that he or she used theories on psychology in order to validate a design. However, there is a purposeful way to use these theories and facts. The designer needs to bare in mind the restraints and the advantages of the human memory. One should not design interfaces or systems that require the user to use the working memory in order to remember a vast quantity of elements. However, one should not take that to mean that a pull-down menu only can consist of seven items or that a user only can understand seven tabs at a time in the user interface. The best way to design a system is to take advantage of the positive sides of both the working memory and the long term memory, while taking care to remember its restraints. Regarding the long term memory an important fact to be noticed by system designers is that humans learn faster and remember stuff more easily if it makes sense to us, and particularly if we take an interest in it. This is something designers can take advantage of both in designing the system, but particularly when teaching the users the system. Being able to use and understand a system is especially important when a system is safety-critical, so designers of such systems should take care to study issues like memory. The ability to correctly understand how the system works and what it contains is a condition that must be fulfilled both for the user to be able to trust the system, and also for the user to be responsible for the operation of the system.

3.4 Summary

This chapter described relevant theories from psychology. I explained what psychology is, namely the scientific study of behavior and mental processes [5]. I presented background information about cognitive psychology and thinking, these are important aspects to consider when designing the user interface, as they describe the study of internal mental processes like problem solving, memory and language. I also included a chapter about gestalt theory which is important in order for the designers to understand how humans perceive the visual user interface.

PART II: USABILITY AND RELATED STANDARDS

Chapter 4 Usability

Usability is: *“The extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use“. [8]*

There are several definitions of usability, I chose this one because I think that it covers the most important aspects of usability.

When developing a system, it is not enough to assume that your system or product meets the user needs, this need to be tested, and tested thoroughly. The designers test whether or not the requirements from the requirement specification is met. Usability is also the degree to which the design takes into account the underlying human psychology and physiology of the user. This is what this chapter concerns itself with.

4.1 User-centered design

User centered design is a way to design in which the user is in the focus of the entire process. In order to do this successfully the designer needs to picture who the end-user is, and what his or her needs are. It is also necessary for the designer to understand the tasks that the user will perform when using the product, this will enable the user to feel the utility value of the product. In order to do so, we should ask ourselves the following question: “What should the criteria for user quality be?” User centered design is a medium we can use in order to achieve user acceptance [10]. Interaction designers use abstract models to illustrate the usability aspect. There are a number of models that are being user by designers as well as users, they are:

- *Mental model:*

  Mental models are the assumptions, conceptions, and stories that people have about themselves, others and everything else in the world around them.

- *Conceptual model:*

A conceptual model is a superior description of the system that you are designing, in the form of ideas about what the system should do, how it will behave and look. The conceptual model should be understandable for the users.

- *The designer model:*

The designer model is the designer idea of how the program should work.

- *System image:*

The system image is the actual program implemented on a machine.

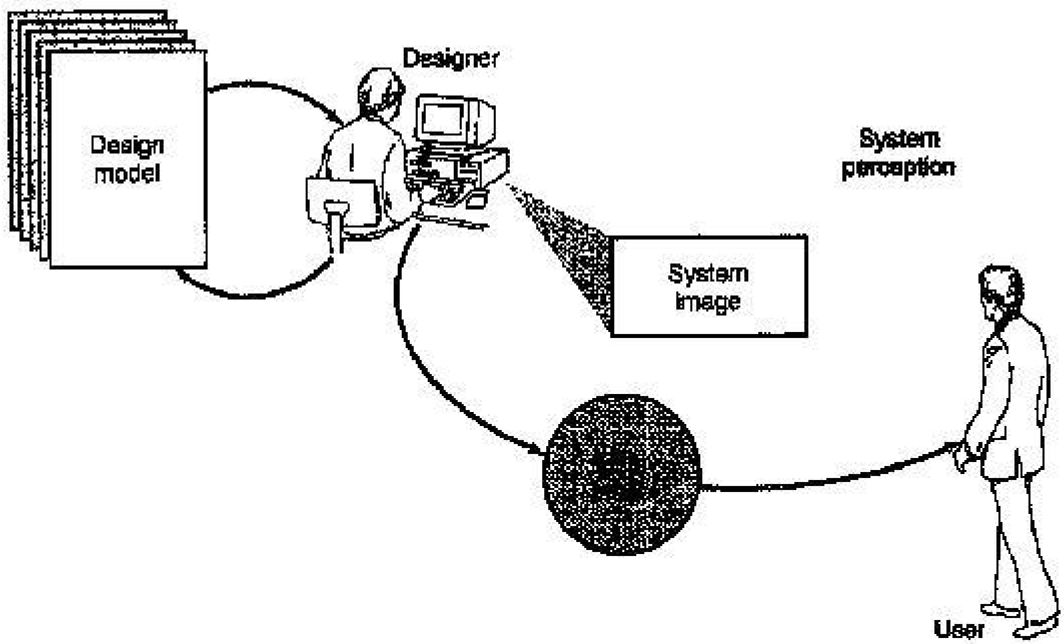

Figure 2-11 Design models. [9]

An example of a really basic mental model is the conception that everyone around you is nice. The user model on the other hand is the users' perception of the program. As the mental model obviously is very important for humans, even though this sometimes is subconscious, we need to take this into account when designing the conceptual model for a product or a system. The problem with our mental models is that our ability to understand them is limited. Humans have a tendency to compromise with their mental models in order to decrease the complexity, when that happens we oversimplify things. What is really important when it comes to the mental and the conceptual models is that the conceptual model should never interfere with the mental model. This will confuse the users, and the users could also get a different idea of the system than what the designer intended. Our task as designers is to communicate our idea with the aid of a program. We should make a program that puts the user in the center "of the action", one way of achieving this is by designing the program using a simple conceptual model, this could mean designing a program in which the user need to remember as little as possible. An example of how you can make this possible is if you design a program that exercises a certain level of familiarity, if the program looks familiar, the users do not need to learn how to use it, as they already know how. When designing a system the designers should take care to notice the factor that is cultural types and also stereotypes. We need to adjust us to the fact that our way of understanding or viewing the system is not the only way. Designers should ask themselves: "Am I designing this system for people like me? Or should I adjust my design to relevant stereotypes and the culture of the users?" As mentioned earlier humans usually act according to certain models or scripts. When users see the design they might expect it to follow a chain of sequences that they have seen before in similar systems. This should not go unnoticed by the designers, he or she should also take care to know their user and that the user expectations of the chain of sequences could differ between different cultures. This should be done in order to avoid unnecessary misunderstandings.

However, it is important to understand that the theory of models is not the only theory you can use when designing a user interface. An example of another theory you can use is Carl Jung's theory of psychological types. The main idea of this theory is that humans behave according to certain psychological types. You can be extrovert, introvert, or a combination of the two. Being extrovert means that you look outside yourself for meaning in most cases, an introvert person on the other hands looks inside him or herself to find meaning. These psychological types refers to how humans relate to others. In real life we often find that an extrovert person is lively and outgoing, while an introvert person may be shy and more cautious when relating with other humans. In his theory Carl Jung also proposes four primary modes of experiencing. There are two rational functions, thinking and feeling, and two perceptive functions, sensation and intuition. Sensation is the perception of facts. Intuition is the perception of the unseen. Thinking is analytical, deductive cognition. Feeling is synthetic, all-inclusive cognition. In any person, the degree of extro-/introversion of one function can be quite different from that of a different function. One can say that most humans tend to work from their most developed function, as this is the most familiar, and therefore the easiest. However, it is when developing the other functions that we widen our personality. The reason that this theory is relevant when developing a system is that it can be helpful to know what function is the most developed in us as designers. We should take this into account when designing the system, as this might color how it ends up.

4.2 Psychological types

The designers should also take into account the psychological types of the users. However, this might involve to much extra-work or simply seem to far-fetched to even consider for many developers. Another important point to take into consideration when dealing with different personality traits, is how nervous individuals will be able to handle the system. The designers should take care that such individuals will not find their system frightening. This also involves individuals that are prone to stress. It is important to develop a system that gives the user a feeling of control. If this is not done, and situations where the user feels that he or she can not control the situation occur, the stress-level increases. However, if the system gives the user a sense of control and predictability, it can reduce the level of insecurity in such situations, and also relieve the feeling of stress. Research shows that some people are more exposed to stress and this could be particularly problematic in safety-critical systems. A way to relieve this problem could be to perform extensive personality tests on individuals considered for such jobs, as this might reveal personality traits like being more exposed to stress. Another personality trait to consider is how more investigative individuals use the system. The designers should not develop a system that requires the user to do everything by the book. If exploring the system leads to catastrophic situations we should revise this.

In order to make a system usable there are certain issues one needs to consider. There are five goals that the program needs to achieve in order to claim to be usable, these are the five usability factors [11]:

1. The efficiency of the system: the system must be efficient for the frequent user.
2. How difficult is the system to learn? The system must be easy to learn for both novices and user with experience from similar systems.
3. Is the system difficult to remember? The system must be easy to remember for the casual user.
4. How is the systems understandability? The user must understand what the system does.
5. Are the users satisfied when using the system? The system must make the user feel satisfied when using it.

The user interface is the aggregate of means by which people (the users) interact with a particular machine, device, computer program or other complex tool (the system). The user interface provides means of [12]:

Input: allowing the users to manipulate the system.

Output: allowing the system to produce the effects of the users' manipulation.

4.3 Graphical User Interface, the guidelines and theories

In an effort to summarize the usability aspects of how the graphical user interface (GUI) could be designed I have decided to include guidelines and theories from three of the most respected men in user-centered design and usability theory. They are Jacob Nielsen, Donald Norman and Bruce Tognazzini [13]. I have also included some guidelines presented by Shneiderman and Plaisant.

Jacob Nielsen is a part of the Nielsen Norman Group, together with Donald Norman and Bruce Tognazzini. In their own words the members of this group are user experience pioneers and advocated user centered design before it became popular to do so, whether this be true or not, they are well respected in their field of work. These days user centered design receives more focus than it used to. Through his years of experience Jacob Nielsen has developed a set of heuristics for usability. From the start these heuristic were supposed to be applied to websites, but in recent years they have become general heuristics for usability design. The reason why they are called heuristics rather than guidelines is that Nielsen himself sees them rather as a rule of thumb than actual guidelines.

4.3.1 Jacob Nielsens heuristics [14]

These ten heuristics are the following, taken from Jacob Nielsens own website:

1. Visibility of system status: the system should be able to show its status to the users, this might be done through appropriate feedback.
2. Match between the system and the real world: the system should use a language understandable to the users, preferably as similar to their own language as possible. System-oriented words should be avoided. Information should be displayed in a way and order that the users expect.
3. User control and freedom: the user will make frequent mistakes, the system should support this, and give the user the means to fix this mistake. The easiest and most familiar way to do this is through undo and redoes functions.
4. Consistency and standards: words that generally mean something everywhere else, especially in relation to computers, should mean the same in the system. Platform conventions should be followed.
5. Error preventions: error messages are good, but what is even better is taking care that the problem will not occur in the first place. This could be done by carefully designing the system with this in mind.
6. Recognition rather than recall: as previously mentioned in the psychology part, the working memory is restricted, and the system should not make the users remember information, objects, actions and options more than absolutely necessary. Instructions of use for the system should always be easily obtainable.
7. Flexibility and efficiency of use: the system should have both the experienced and the novice user in mind. This may be done by allowing the experienced user to speed up the interaction with help of accelerators. This should remain unseen by the novice user. The system should also allow the user to tailor frequent actions.

8. Aesthetic and minimalist design: dialogues with the users should be kept at a level in which no more than the absolutely necessary information is visible. If too much information is present it will compete with the relevant information of the users attention.
9. Help users recognize, diagnose and recover from errors: when displaying error messages they should follow the previous heuristic and present the problem as well as the solution in an understandable and orderly fashion.
10. Help and documentation: the system should allow for the user to use it without documentation. However, if needed, the documentation should always be available.

Bruce Tognazzini [15] is another usability expert working with the Nielsen Norman Group. He mentions that taking people who are color blind into consideration as a key principle when developing effective GUIs. Often we might be tempted to use elaborate color schemes in our GUIs, however, as a big proportion of the users might suffer from color blindness, this should be done with caution. By saying this it is not meant that one should not use colors at all, as this would make a boring interface. What is meant is that one should take this into consideration, and not make colors play a key part in understanding the system. Tognazzini also mentions Fitt's law, which says the following: "The time to acquire a target is a function of the distance to and size of the target". [16] It is also important that the user will not find the program to be to slow. Every unnecessary part of the program, which might slow it down, should therefore be removed. This also goes for feedback, which should be given within a reasonable time. An example of feedback is whether action instigated by the user was performed or not. Another tool at hand for the system developer to use is metaphors. This could, if used right, make the program easier to understand and use. An example of such a metaphor is the paper clip that is often used to denote an attachment to an e-mail. Bruce Tognazzini urges system developers, or designers to think about the potential users when choosing a font type for the system, if it is too small it could be hard to read for older people, or people with impaired eyesight.

4.3.2 The eight golden rules of interface design

Shneiderman and Plaisant [17] present what they call “Eight golden rules of interface design”:

1. Strive for consistency: if a sequence of actions means one thing in one situation, it should mean the same thing in another situation. The terminology should strive to be consistent and employed throughout the system.
2. Enable frequent users to user shortcuts: when users become more experienced in using a system they will want to use shortcuts in order to make the interaction with the system faster and more efficient, the system should cater for this need.
3. Offer informative feedback: for every action the user performs he should receive feedback that it was done, the less frequent the action is, the more important is it that the feedback is noticed.
4. Design dialogue to yield closure: when the user is performing a sequence of actions these should be divided into a beginning, the middle and the end. The system should clearly state each of the different stages, especially the ending, as this might give the user a sign of closure and sign that he may move on to the next sequence of actions.
5. Offer simple error handling: as the user inevitably will make mistakes, the system should give the user a simple way to fix this. It should also prevent the users from doing serious errors. The system should give the user the means to handle such situations.
6. Permit easy reversal of actions: by offering this the system relieves the user of some of the pressure that comes from using it. This means that the user does not have to be anxious of making errors as he knows that they can be undone.
7. Support internal locus on control: when the users get more experienced with the system, they want more and more to be in control of the system, to be the initiator of actions, not the responders. The system should cater for this.

8. Reduce short term memory load: the limitations of the working memory should be taken into consideration and the user should not be forced to remember more than necessary.

These rules are somewhat similar to the heuristics proposed by Jacob Nielsen.

4.4 Summary

This chapter described usability. Usability is the degree to which the design considers underlying human psycological and physiological issues. I explained hiw humans relate to each other and how this potentially could affect the design of the user interface. To make this easier I included guidelines and theories for the design of a user interface.

Chapter 5 User interface standards

In this chapter, I present the “Rules for Classification of Ships/High Speed, Light Craft and Naval Surface Craft” [18] and ISO 11064, Ergonomic design of control centers, which is a standard that was approved by CEN (European Committee for Standardization) on the 15th of December 2000 [19]. This particular standard was made in order to create a generic framework where the requirements and recommendations for ergonomic and human factors in control centers could be used. This framework should be used when designing or evaluating control centers with the goal of minimizing the potential of human failures.

The standard is relevant in my thesis because it is an important example of a tool to be used by designers to achieve a higher level of safety, and this is why I have dedicated a chapter to it. It is important to notice, that there are several other standards that I could have focused on or described in the thesis. Examples of such standards are the DIN 66234 standard, “VDU work stations: Principles of ergonomic dialogue design” (1988), ISO 13407, “Human-centered design process for interactive systems” (1999) or the ISO 9241, “Ergonomic requirements for office work with visual display” (1998). The reason why I choose the ISO 11064 standard is as above mentioned that it specifically concerns the design of control centers. Control centers are an important part of both the bridge on the ship, and also the engine room, naturally a good design of these should be a focus area.

The standard represents one of the issues that are being dealt with in the questionnaire.

5.1 ISO 11064

5.1.1 Important human characteristics

The human characteristics that are related to the evaluation or design that the standard proposes, should include not only the fundamental physical human qualities and limitations. They should also include and emphasize the unique human cognitive skills. This includes having knowledge of how operators might feel and behave in specific situations. An overview of how operators cooperate with the computers and inside the control center, as well as how they cooperate with the designed objects included in the machines and environment should also be looked at. In my thesis this standard is relevant because it concerns a very important issue in the problem to addressed, namely how the control centers should be designed.

5.2 What the standard is all about

The standard was made in an effort to guide designers in making a good control center [19]. This is done by presenting a set of phases that the design should go through, these phases make a framework. Supporting these phases are steps which are a part of the phases. In order to go through the phases, the steps need to be passed through as well. In addition to the phases and steps, the standard mentions several cognitive and conceptual issues that need to be considered and evaluated. Chapter 5.4 presents the cognitive and conceptual issues that the standard emphasizes. Figure 5-11 shows how the phases and steps are connected, and which steps are a part of which phases.

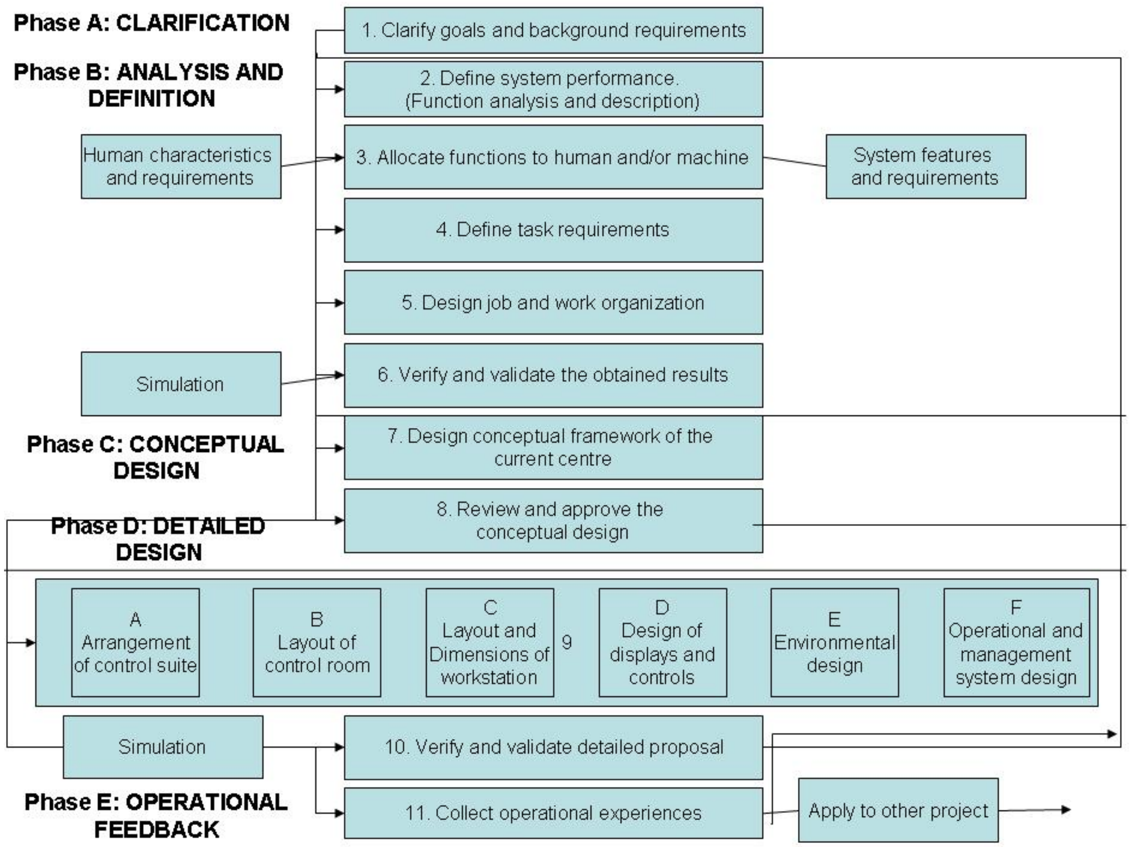

Figure 5-12 Ergonomic design process for control centers from ISO 11064: Ergonomic design of control centers, Part 1: Principles for the design of control centers (2000) [19]

Figure 5-11 shows the framework of phases and steps that will be presented in detail in chapter 5.5. The framework consists of five design phases for the control center design process. Figure 5-11 also shows the numerous feedback paths available, they relate to the iterative nature of designing solutions for complex problems.

In addition to the phases and steps, the standard presents a set of general considerations and principles for ergonomic design. There are nine principles, and I have presented them in chapter 5.6.1.

5.3 The operator

It is important that the operator understands his/her task. Another important factor that needs to be considered is the fact that human error never can be fully eliminated. As a result of this, all designs need to strive to be human error-tolerant. An important tool that may be used in order to achieve this is risk-assessing, this is done to get information about human errors. Furthermore, it is important that the users are a part of the development of both the tool and the control room. This helps the user to achieve a sense of ownership over the tool that he is using. Both experienced and future users should be a part of this process.

5.3.1 Cognitive and affective support

When allocating functions to humans, it is important that some cognitive and affective support criteria are being taken into account. Such considerations include:

- Overall authority should be maintained, this could be done through mode selection
- An understanding of the state of the machine should always be facilitated
- When humans use a system, they should have the feeling that they are useful
- The situational awareness should always be maintained
- Educational and training need should be supported

There are also some considerations that should be taken in order to avoid such characteristics to the system, these include:

- The avoidance of repetitive and boring tasks
- The improvement of the system efficiency and reliability

Several of these criteria are mentioned in the psychology chapter regarding how to design for human operators. In my follow-up questionnaire I have also included several questions related to the considerations of such issues as the above mentioned.

5.3.2 Conceptual design

The conceptual design is a part of phase C, as described above. The purpose of the phase is to develop a comprehensive design project of a control centre that satisfies the allocated functional and task requirements, job descriptions and organizational plans that were established in phase B. See phase B above. The conceptual design includes the physical attributes of the control centre, the furnishings and any special amenities.

5.3.3 The allocation of functions/tasks to humans and/or machines

Below is a table that tackles the issue of which functions are suitable for humans, and which are more suitable for machines.

No.	Step	Procedure
1	Mandatory allocation. Allocation to meet safety and/or regulatory requirements.	1.1 For mandatory automatic functions/tasks, allocate to machine. 1.2 For mandatory manual functions/tasks, allocate to human
2	Attempt at preliminary allocation in terms of human traits, abilities and characteristics with a view to ensuring the safety and reliability of the system's performance. Allocation according to performance characteristics.	2.1 Re-design system to avoid tasks which cannot be carried out satisfactorily by humans and/or machines[a]. 2.2 Allocate functions/tasks which cannot be satisfactorily carried out manually[b] to machines. Treat as mandatory automatic functions/tasks (see 1.1 above). 2.3 Allocate functions/tasks which cannot be satisfactorily automated[c] to humans. Treat as mandatory manual functions/tasks (see 1.2 above). 2.4 Initially, allocate machine preference[d] and human preference[e] functions/tasks to machines and/or humans respectively. 2.5 Initially leave without preference functions/tasks[f] unallocated.

3	Allocation according to cognitive and affective support criteria. Complementary or flexible allocation from the viewpoint of ergonomics and system efficiency.	3.1 Consider re-allocation of without-preference, machine preference[d] and human-preference[e] functions/tasks according to cognitive and affective criteria. 3.2 Consider complimentary or flexible allocation, which gives users the ability to change the allocation.
4	Ascertain feasibility of automation.	4.1 Determine whether functions/tasks allocated to humans can be implemented effectively using available automation technology.
5	Ascertain feasibility of human performance. Select tasks which are to be supported by operator support systems to assist with signal detection, information acquisition and decision making.	5.1 Assess whether the functions/tasks allocated to humans can be implemented effectively, assuming the availability of operator support systems. Determine whether such systems can be implemented using the available level of technology.
6	Evaluate allocation. Determine need for iteration and revision.	6.1 Repeat allocation procedure if the proposed allocation of functions/tasks is impractical or requires further refinement, or if steps 5 and 6 reveal unacceptable technical limitations.

[a] Functions/tasks linked to neither humans or machines and performed unsatisfactorily by both humans and machines. System should be redesigned to avoid such tasks.

[b] Functions/tasks linked to machines. They are carried out so badly by humans that they should be assigned to machines (automated).

[c] Functions/tasks linked to humans. They are carried out so badly by machines that they should be assigned to humans (manual).

[d] Machines preference functions/tasks. They are carried out better by machines, to which they should be assigned, unless dictated otherwise by other criteria.

[e] Human preference functions/tasks. They are carried out better by humans, to whom they should be assigned, unless dictated otherwise by other criteria.

[f] Without preference functions/tasks. They are carried out satisfactorily by both humans and/or machines. Other criteria may determine assignment.

Table 5-1 Basic procedures for the allocation of functions/task to humans and/or machines from ISO 11064: Ergonomic design of control centers, Part 1: Principles for the design of control centers (2000). [19]

It is important to notice that the steps of the table are not to be confused with the steps of the phases. Table 5-2 provides basic procedures for the allocations of functions to humans and/or machines. The objective of the table is to clarify how cognitive and affective support, as explained above, and ergonomic considerations should be considered. Ergonomic considerations may include human abilities, human characteristics and human dignity, all of these should be fully taken into account.

5.4 <u>The framework for an ergonomic design process</u>

This framework is divided into five phases. Typically, all of the phases should be executed [19].

A. Clarification: the purpose, the context and the resources should be clarified in this phase. Possible constraints should also be assessed in this phase. Existing situations that could be relevant should be considered and possibly used as a reference later on.
B. Analysis and definition: the performance and demands of the control centre should be assessed. This culminates in preliminary functions allocation and job design.
C. Conceptual design: the initial layout for the room is developed, this includes the design for furnishing, displays and also controls. The communication interfaces that were deemed necessary in phase B should also be a part of the design.
D. Detailed design: more detailed specifications for the design, than what was done in phase C, should be developed. Specifications for the construction and/or procurement of the control centre, its contents, operational interfaces and environmental facilities are developed.
E. Operational feedback: in the aftermath of the design a review should be conducted. This review should identify what went wrong, and what went right, i.e. the failures and successes. This is done in order to apply what was learned on subsequent designs.

5.5 The general considerations and principles of ergonomic design

5.5.1 The principles

1. Application of a human-centered approach: The objective of this principle is that the designers should be able to design adequate working conditions. Human safety, health and wellbeing should be taking into account, as well as technological and economic efficiency. ISO 11064 concerns how this should be done at the control centers in particular. The basic human physical capabilities and limitations should be taken into consideration, as well as the unique cognitive strengths in human psyche. The operators and how they interact with the environment should also receive special attention.
2. Integrate ergonomics in engineering practice: ergonomics should be integrated into the guidelines for the project, so that designers and engineers always remember taking it into consideration in the development process.
3. Improve design through iteration: As the design process is an iterative one, this should be the case in the development of the control centers as well. By iteration it is meant that the evaluation of the different steps shall be repeated until the requirements are fulfilled. Figure 5-12 is an effort to explain this.

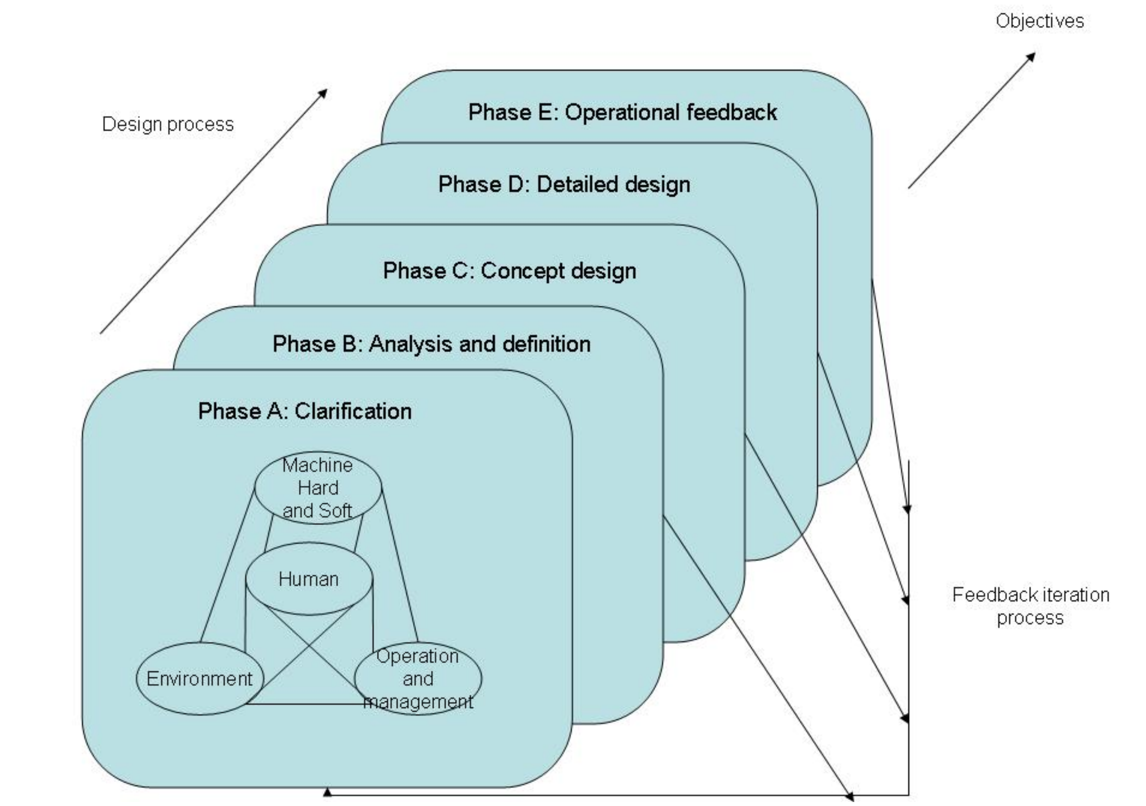

Figure 5-13 Ergonomic approach to system designs from ISO 11064: Ergonomic design of control centers, Part 1: Principles for the design of control centers (2000). [19]

4. Conduct situational analysis: Before starting the design, a situational analysis should take place. This analysis might analyze existing conditions, or similar conditions. The grounds for such an analysis are that the functions of the future system can be fully understood and anticipated.
5. Conduct task analysis: The tasks that will be given to the individual control room operators, as well as significant users of the control centre, shall be fully understood.
6. Design error-tolerant systems: The problem is that human error can never be fully eliminated. With this in mind designers should always try to achieve as error-tolerant a design as possible. An important tool to be used here is risk assessment, in which information on human error is obtained.
7. Ensure user participation: If the users of the system have a sense of ownership, it will increase the satisfaction with the system. User participation also means that

the long-term human-machine interaction is optimized, this is also because of the sense ownership that is achieved. In the design process experienced user may contribute with valuable empirical contributions.

8. Form an interdisciplinary design team: As mentioned in the introduction to the thesis, it is vital that systems are understandable not only to the practitioners who have made it. This is why an interdisciplinary design team should be formed. The team should oversee and influence all phases of the design project. How the teams should be put together depends on the overall project scopes, or on the phase the design is in. If the process involves an existing system, both users and user representatives should be involved in the team. If it is a new system, both experienced and future users of the systems should have a chance to be part of the team.
9. Document ergonomic design basis: Internal documents reflecting the ergonomic design basis for the project should be developed. Whenever there is a change, this document should be updated.

5.6 My assessment of the standard

The work that this standard tries to do is very important and if used right, this standard could be of real help for designers of control centers. However, in my view, the standard is hard to understand, and it might come across as a bit untidy. By untidy I mean that it is hard to get a general impression with all the principles, steps and phases in the standard. As far as I can tell this could potentially be a very good tool for the designers of control centers for the bridge on the ship. It addresses the fact that there are some tasks/functions that the computer performs better than humans, and vice versa. The standard also makes an effort to explain why this is, which is important that the designers understand. It seems reasonable that if the designers do not know why they are supposed to do something that takes an effort, they would rather not do it. These issues are also described in my Psychology chapter.

5.7 "Rules for Classification of Ships/High Speed, Light Craft and Naval Surface Craft"

DNV has a set of classification rules [18]. Part four, chapter nine is the part that I have studied. In this chapter a section on user interface is included. It is important to notice that the part concerning the user interface is a very small part of part four, chapter nine. This section concerning user interface, deals with design and arrangement of the workstation, user input device and display unit design and the design and work environment of permanently manned workstations.

The location and design of the user interface should consider physical capabilities of the user, and it should comply with accepted ergonomic principles. Section six of chapter nine gives requirements for the user interface. These requirements are supposed to ensure a safe and efficient operation of the systems installed. This should be done according to the following objectives:

- Controlled work load adapted to the user(s) in all modes, including for system degradation
- Ensure fast and correct decisions
- Ensure fast and correct user actions
- Avoid unnecessary stress.

The classification rules takes a different approach than the ISO 11064 standard does. They go into detail on how the screen should appear, it explains how the font should be as well as the use of colors. The rules also concern the location of visual display units and user input. The ISO 11064 standard takes a more top-down approach and does not go into such details.

5.8 Summary:

This chapter described relevant user interface standards, with emphasis on the ISO 11064 standard. I described other standards that could have been used in the maritime industry, and explained why I chose to use the ISO 11064 standard. I also included some information from part four chapter nine of the rules for classification at DNV, to show how they do it.

Chapter 6 Accidents due to poorly designed user interfaces

As a means of explaining what can go wrong and why in a system, I have chosen to include this chapter in the thesis. The chapter includes a presentation of the Three Mile Island [20] accident. It includes an explanation of what went wrong, why, and a presentation of the aftermath of the accident. There are many accidents that could have been used to illustrate the problem. The reason why this accident is covered is that this accident is commonly used to illustrate the problem with poorly designed interfaces.

I have also chosen to include a description of some other accidents, and relevant information related to these.

6.1 The background for the Three Mile Island accident

Three Mile Island is located ten miles southeast of Harrisburg a city in Pennsylvania, USA. Three Mile Island has two nuclear power plants, namely TMI-1 and TMI-2. Together they have a capacity of 1700 megawatts, this is enough to supply 300000 homes with electricity.

On Wednesday, March 28th, 1979, at 4 A.M., several water pumps stopped working at the nuclear plant at Three Mile Island. In the aftermath of this accident the Kemeny Commission investigated the accident, and concluded that: "a series of events-compounded by equipment failures, inappropriate procedures and human errors and ignorance- escalated into the worst crisis yet experienced by the nation's nuclear power industry". [20]

What actually happened on the morning of March 28th was that a series of feed water system pumps, which supplies water to the TMI steam generators stopped working. This meant that water no longer flowed to the steam generators, and soon there was no steam.

The steam has two functions, it runs the generator to provide electricity, and it also removes some of the heat that the water in the reactor carries. In turn, the stopping of the generators lead to the automatic shut down of the turbine and the generator. All of this happened in the first two seconds of the accident. When the feed water stopped coming, the temperature of the reactor coolant increased and the rapidly heating water expanded. The pressure in the reactor increased and a pilot-operated relief valve, a PORV, opened to relieve the steam. However, this valve is only supposed to relieve pressure just long enough for the core to cool down. If too much water flows through the generator the pressure will fall so much that steam voids will form in the core and pipes of the first cooling system. In turn these steam voids, which look like some kind of bubbles, will prevent the cooling fluid to flow freely, and the nuclear fission will start all over again. The accident escalated when the PORV stayed open for too long. This meant that the cooling fluid from the core poured out through the open valve. This was unknown to the operators, as they thought that the PORV had closed as it was supposed to. In addition the control board in the control room showed the PORV as closed, so the operators really had no way of knowing what was happening, short of actually checking it out by themselves. It was expected that the pressure would rise again, shortly after the PORV had closed, but as it was in fact still open, this did not happen. As a result one of the two cooling pumps for the reactor started automatically while the other was started manually by the operators. This happened 13 seconds into the accident. For a minute or two everything seemed to be working, at least from the operators' point of view. However, this was happening "behind the scenes", the steam generator boiled itself dry since no fluids made its way into it, and the cooling fluids in the reactor got hotter again. Since the core continued to lose its water, the pressure in the cooling system fell rapidly. The problem with this accident was that emergency systems kept starting, sometimes out of place. Two minutes into the accident, an emergency system for high injection pressure started. This system poured water into the core at high speed. The operators had this system running at max for two minutes, before they reduced the speed drastically. However, as the water was boiling out through the PORV this did not help much. As the core continued to boil without water, the core got more and more exposed. This is the most dangerous situation that can occur in a nuclear plant. In time the container might melt, and radioactivity might be released. Fortunately, after two hours, the operators discovered the open PORV and closed it, had they waited only 30 minutes longer a full melt down might have been the result.

6.1.1 What caused the accident?

The official investigation of the Three Mile Island (TMI) accident was executed by the Kemeny Commission.

The initial reaction to what caused the accident was that the operators were largely responsible for it. However, the Kemeny Commissions' report on the TMI accident contains 19 pages of recommendations, two of them deal with technical matters and 17 deals with management concerns. In specific these 17 pages concerns itself with management, training and institutional shortcomings of the nuclear industry. The conclusions is that the industry as a whole need to deal with its attitude towards safety and regulations.

6.1.2 How did it get to this?

One of the officials at Three Mile Island testified that at some point, the workers at TMI had developed a mindset in which the equipment they used was infallible. This came to as a result of repeated assurances that the technology was safe. NRC assembled a post-TMI Lessons Learned Task Force and they noticed the following regarding the mindset in serious accidents: "it is probably the single most important human factor with which the industry and the NRC has to contend." However, this frame of mind was made obvious even outside the industry itself when the French president shortly after the accident claimed that something like this could never happen on French soil. Soviet authorities also revealed this mindset when they too claimed that their nuclear power plants were safe and that the probability accidents like this at Soviet soil were extremely slight. As we all know this just was not true as the Chernobyl accident of 26th of April 1986 happened on Soviet soil. British government on the other side continued to claim nuclear power as the safest energy source until one month prior to the accident at Three

Mile Island. This mental frame of mind is part of what makes us ignore all the warning signals that might be available prior to accidents. Another example of an accident where there were warning signals that were ignored is the Titanic accident. Prior to the accident they received warnings that they could encounter icebergs. This was mostly due to the frame of mind that the Titanic was unsinkable. Another evidence of this frame of mind regarding Titanic was the fact that the supply of life boats was so short, they were considered unnecessary and an inconvenience. Many accident investigations uncover a sincere concern for safety in the organization, but the organizational structures prevent them from implementing this concern. The lack of appropriate communication channels regarding safety makes the problem worse. There should always be at least one person in the organization that has the overall responsibility for safety. This will help prevent the diffusion of responsibility and authority for safety that is often apparent, as well as problems with decision making at the wrong levels of management. Another problem is that the safety personnel have a low-level status which leads to these types of jobs not being sought after by the employees. On the other hand the personnel that actually have some insight into the safety matters get excluded when it is time for the actual critical decision making.

Regarding the actual situations where safety is at risk they may reveal situations that were not anticipated by the designer of the program, and therefore not included in the operators training, the operators often work at the limits of their perception. However, situations like these may cause the operator to construct erroneous mental models of the systems state. The problem with such mental models is that there is often no way of detecting the correctness of the model without after-the-fact knowledge, and obviously this is not available until after the accident. What is hard for outsiders to realize is that at the moment of the accident, the mental model constructed by the operator was just as likely to be correct as the real model at the time they were constructed. An example of this fact being hard to understand by outsiders is the Three Mile Island accident, as this accident is widely thought to be the result of operator error. However, when you examine this accident more thoroughly it is apparent that the factors involved suggest that the judgment of the operators is a classic case of misattribution of an accident. This misattribution involves blaming the operators and the use of hindsight to label the actions of operators to be erroneous. However, as previously mentioned the use of hindsight is a tool not available to the operators at the time of the accident, and therefore not a good measure of guilt. The accident sequence should therefore be considered to be initiated and compounded of equipment failure. There just was not enough information available to the operators in order for them to make the 'right' decision. Technically, the operators made several 'wrong' decisions, the major one being the decision to throttle back on two high-pressure injection pumps to decrease water pressure, thus allowing the core to become uncovered and overheat. However, this decision normally would have been a good decision, and the information necessary to realize that this was not the right decision was not available to the operators. Rick Hornick, a past president of the Human Factors Society says: "The chain of events at TMI was not the result of immediate human errors in the usual sense. Rather, it reflected the prior failure of owners, managers and engineers to appropriately design interactions between humans and machines". Further, Victor Gilinsky, a Nuclear Regulatory Committee Official argues: "In emphasizing the human failures and thereby vindicating the equipment, the report does not stress enough that the equipment could have been designed to avoid this kind of trouble". Malcolm Brookes backs up the previous two by saying: "…the fundamental errors were in system design".

But what actually happened? At TMI the designers had failed to anticipate and therefore correctly handle the conditions that actually occurred. Furthermore they had assumed that the system was self-regulatory so they did not train their operators nor the system to intervene efficiently. Part of the problem is that the shortcomings of the operators in handling the system are also the shortcomings of the designers. Designers have been found to have difficulties in assessing probabilities of rare events and a bias against considering side effects. They also have a tendency to overlook contingencies and a propensity to control complexity by concentrating only on a few aspects of the system. In addition they have a limited capacity to comprehend complex relationships. [20]

Prior to the Three Mile Island accident human factors were for the most part ignored in the design of nuclear power plants. It is widely recognized that the TMI accident was a result of a lack of appropriate design of the interactions between humans and machines. An example of how the work and decision making of the operators was made difficult at Three Mile Island is the fact that so many alarms went off at the same time that the printer fell behind by as much as two hours in printing them. Also the instrumentation gave the unsatisfactory information which lead to the operator making decisions that made the situation worse. The topic of erroneous mental models plays a part here as well as en erroneous model is difficult to change once it is present. In practice this might mean that a warning that clashes with our mental model might get ignored in benefit of other signals that fit our model better. This brings us to an important subject, the alarms and their behavior. More specifically how routine alarms should be distinguishable from safety-critical alarms. The situation that emerged at TMI was that hundreds of alarms went of at the same time, but little distinguished them from each other in terms of importance, sequence and timing.

6.2 Summary

This chapter was an effort to describe how disastrous poorly designed user interfaces can be. I described the Three Mile Island accident, as this a good example of a poorly designed user interface and the effects this can have.

Part III: RELEVANT BACKGROUND FROM THE MARITIME INDUSTRY

Chapter 7 - Atomos IV and the ISO 17894 standard

In this chapter I will explain what the Atomos IV [22] proposition is. This proposition is relevant in my thesis as it is an effort made from the maritime industry itself to increase the level of safety. However, it is important to notice that this proposition does not only deal with the user interface. Although it is not the major part of the proposition, it is my main focus when presenting it.

This chapter also includes a description of the ISO 17894 standard, with focus on the issues related to the user interface. The standard is developed from the Atomos proposition

7.1 The background

The ATOMOS and DISC initiatives are realized through a series of projects, designed to develop and test open, user-centered, integrated control-systems. The strategy that ATOMOS is pursuing is to develop marine safety and efficiency by combining evaluation of user needs with the development of new technology [21.

Integrated Ship Control (ISC) took a new turn during the ATOMOS I project. A framework and new technology was developed in order to get a total integration of information. With the ATOMOS II project one realized that ISC in as huge a degree as possible should be developed both with the user in mind, and particularly with regards to requirements and possibilities.

With the ATOMOS IV project one tries to take into account both the increasing degree of integration of marine computer systems as well as the increasing awareness of software-related safety issues [22]. The ATOMOS IV project has five themes [22]:

1. The development and validation of a process and tool to support equipment upgrade strategy for the European Fleet. This is the main deliverable for the project.
2. A trial retrofit of an advanced control system to an icebreaker. This will involve a detailed analysis of the requirements, development and/or adaptation of components, evaluation and refinement of the user-system interface using simulator trials, integration and installation of the complete system and sea trials to prove the concepts and operational capability of the system.
3. Full verification and validation of the retrofit project. The project will use a risk-based approach and perform all the evaluation activities required by the latest standards in safety related IT systems development. These will be subjected to third party assessment. This assessment will be a validation of a new approach to the problem of certification of complex systems.
4. Project evaluation. The project will be extensively evaluated for safety and cost-benefits of retrofit. The findings will feed back into theme 1.
5. Project dissemination. In order to achieve maximum impact from the work the activities on, and findings of, the project will be actively disseminated to all relevant parties using techniques ranging from web sites to development of standards.

The motivation of the research is a widespread acceptance of the results gathered, and furthermore, an adoption of the results generated.

7.1.1 The templates

A set of templates for making submission statements attesting the conformance with SOLAS Regulation V/15 2002 was made. The set is put together as follows:

1. A pocket card for day to day changes. This is supposed to be a performance aid, perhaps in the form of a PDA or something that can be easily carried around and synchronized [24].
2. A form for attesting conformance to minor changes [25].

3. A more extensive form with guidance for preparing submission statements for major retrofits and new builds [26].

The three templates should accommodate changes of decisions of different scale, and is intended to give guidance to Administrations and owners making submissions in the interpretation of the Regulation and its application. The set of templates proposes a common treatment of the design in order to make it consistent and integrated. The Regulation and its templates concern all ships, all the time. In particular it should be applied to both the design and the arrangement of navigational systems as well as equipment on the bridge. It also applies to the procedures relevant to the bridge and the design of the bridge. However there are issues that prove to be more difficult than others.

7.2 Human Computer Interaction (HCI)

HCI is one of these issues, HCI design is difficult to specify in a manner that is easy to assess. Good bridge layout on the other hand can be assessed easily.
When making decisions there are several factors that need be accounted for:

- Manning operations and procedures
- Equipment and system design
- Bridge layout

One need to take these into account when:

1. Defining the scope of a decision
2. Identifying the potential risks associated with a decision
3. Identifying the means of mitigating the risk associated with a decision

In the ATOMOS regulation there are seven aims, and it is required that these decisions should be made with the aim of meeting the aims. The seven aims are as follows [22]:

1. Facilitating the tasks to be performed by the bridge team and the pilot in making full appraisal of the situation and in navigating the ship safely under all operational conditions.
2. Promoting effective and safe bridge resource management.

3. Enabling the bridge team and the pilot to have convenient and continuous access to essential information which is presented in a clear and unambiguous manner, using standardized symbols and coding systems for controls and displays.
4. Indicating the operational status of automated functions and integrated components, systems and/or sub-systems.
5. Allowing for expeditious, continuous and effective information processing and decision-making by the bridge team and the pilot.
6. Preventing or minimizing excessive or unnecessary work and any conditions or distractions on the bridge which may cause fatigue or interfere with the vigilance of the bridge team and the pilot.
7. Minimizing the risk of human error and detecting such error if it occurs, through monitoring and alarm systems, in time for the bridge team and the pilot to take appropriate action.

Several of these applies to the user interface, which is what I am focusing on in this thesis, in particular aim 1, 3 and 7 applies directly to the user interface aspect.
The Regulation goes further by also suggesting how manning and operations should work and which equipment and what training should be used to achieve the aims, I will present the training suggestions for aim 1, 3 and 7 as I feel these are the most important, in my context.

7.2.1 The goals relevant to HCI

Aim 1: The training will need to support good bridge watch-keeping and operations. If a loss of equipment or crew occurs, failure conditions will need to be reviewed to check for safety. In order for this to work the equipment should support operation in all situations.

Aim 3: The bridge team, and in particular the pilot should have convenient and continuous access to essential information. This information should be presented in a clear and unambiguous manner. To achieve this standardized symbols and coding systems for controls and displays should be used. A stepping stone to achieve this is that the user interface will need to be consistent and well-designed. Also the need for it to be able to supply continuous access must be considered, and information that is essential needs to be identified as such. Cross-system consistency will be required.

Aim 7: In order to achieve this aim the alarm management should ensure that set points and thresholds are at values that give enough time. One needs to develop procedures that take this into consideration and help to avoid and recover from human errors. The equipment used should have a design that addresses human error prevention and the recovery from them. This includes alarm philosophy for acceptance, inhibitions and transfer etc.

7.3 Ship Control Centre design

The approach that is used within ATOMOS has been to consider the Ship Control Centre (SCC) design at four levels:

1. A context-of-use and a description of the mission of the vessel should be at the highest level.
2. Function and task analysis lies at the second level.
3. Task allocation, based on typical scenarios derived from the first two levels should be included on the third level.
4. Finally, the fourth level deals with issues concerning the implementation.

This approach is consistent with ISO 11064 which I explain in detail in chapter 5, this thesis.

However, when implementing a plan like this in the marine sector. One is bound to run into some problems. The equipment suppliers, naval architects and owners have lacking knowledge about Bridge Resource Management (BRM) and relevant technical staff, should in order to break down this barrier, receive training that include automation awareness and an understanding of the SOLAS Regulation, which is what Atomos is based on. The marine sector as a whole is still coming to terms with the introduction of complex computer systems. This added with the fact that the pace at which new ships are built gives little chance for the data gathering and analysis to mitigate human element risks poses as a big organizational boundary. Luckily ATOMOS has been an important application of human-centered design to the marine sector, and through the experience gathered through the project is serves as an important help when introducing the more widespread application of human-centered design in the marine sector.

7.4 The ISO 17894 standard

This is an ISO standard from 15th of March 2005. The topic of the standard is Programmable electronic systems (PES) and how they replace electromechanical systems and/or crew tasks. The standard is based on the Atomos IV proposition, and as such it is a natural part of the thesis. In this part of the thesis I will present the standard, and the most important issues.

7.4.1 General principles for the development and use of programmable electronic systems in marine applications [27]

The PES will involve a new technology and this can both invite to an integration of the new and the traditional system components, including crew tasks, as well as provide for more complex behavior. This will the lead to a multitude of benefits like the increase in efficiency and in safety through improved monitoring, which could also lead to increased situation awareness on the bridge, among others. However, the writers of the standard recognize that PES like all complex products, might contain defects, and the major problem with the defects in PES is that they can not be seen. They can not be tested using traditional engineering methods. With the combination of complexity, replacement of a combination of mechanical and crew functions with computer hardware and software, and industry practice in developing and maintaining marine PES leads to a wide range of potential defects which cannot be guarded against by prescriptive standards.

Management, monitoring or control of a ship, are areas which might experience the effects of the PES, some of them are:

- The abilities and efficiency of the crew has the potential to increase,
- Changes in the organization of work, through the automation of lower-level tasks,

- Integration of systems through use of several systems by one seafarer,
- The role of the crew might shift as the PES takes over several of the jobs, the crew, as a result, might get more into the management of the PES,
- Interfaces change, and as a result the crew views the ship differently,

The use of PES on the ship means that it becomes one total system of inter-linked PES and the crew works together in order to fulfill the operator's business goals for the ship.

7.4.2 The life cycle of the marine PES

An important issue in ISO17894 is the life cycle of the marine PES [27]. This is a mechanism to assist in the production and operation of a system. The life cycle proceeds through a series of stages. Each stage has one or more processes defined and the movement through the stages is whenever the process or processes of each stage is completed. Each process may produce output in the form of documentation, but it may also produce different kinds of output. There are three main processes: management, verification and validation. These could be present at each stage in the life cycle. The verification and validation processes help discover discrepancies between the requirements and the developing PES. As a result the verification and validation processes should be applied in the early stages, but also throughout the entire life cycle. Early identification of mismatch between the requirements and the actual PES is important because the cost of remedying defects increases approximately 10 times for every stage of separation between the defects and its correction. The life cycle itself ends when the system is no longer in use. This can lead to either of two things, the system can be modified for further use, which would initiate a new life cycle, or the system could be disposed of. However, between these two points the system can exist in many forms, like as an idea, or on paper.

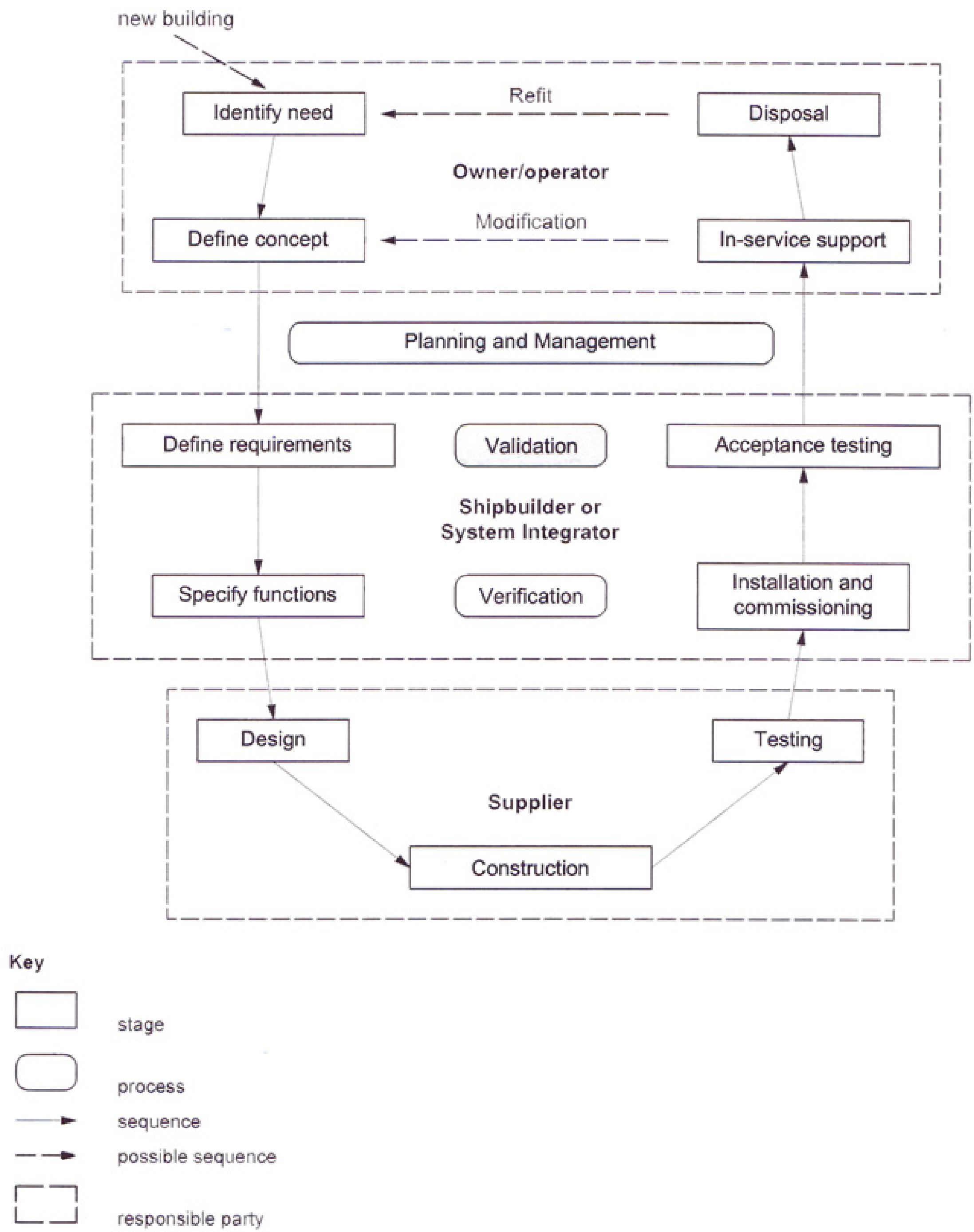

Figure 7-14 PES life cycle stages. [27]

7.4.3 The 20 principles that is proposed for marine PES [27]

The PES shall be demonstrably suitable for the user and the given task in a particular context of use. It shall deliver corrects, timely, sufficient and unambiguous information to its users and other systems. The hardware and software of the PES shall respond correctly throughout its life cycle.

1. *The PES shall be free from unacceptable risk of harm to persons or the environment.*

This is the general requirement for the safety of marine PES. IMO (International Maritime Organization) has proposed methods and measures by which cases can be justified to determine the risks involved. The PES can be analyzed and evaluated, in order to determine the risks in a specific context of use. However, this context should be clearly defined as well as understood by all involved parties. The potential misuse of the PES should also be taken into consideration and the risks should be evaluated, as well as the evaluation of normal usage. The most important point of this principle, is to make the hazards that come with the usage of PES, known and understood. The introduction of risk reduction features which are external to the PES so that one can ensure that the safety levels are acceptable. The features may include warning notices, issuing personal protective equipment to users or working to create special procedures or training to use. The evaluation and analysis should include each element of the PES, the reasons for this is that each level has its own level of risk. Before the construction of the PES, the risks should be determined and minimized, possible eliminated all together. All the parties involved in the PES are obligations in respect of this principle. However how involved the different parties are vary widely depending upon the PES, the context of the use, and who is responsible for its development, supply and maintenance. For example, the owner or operator should address top-level hazards in respect of the overall ship and its major systems. It is the suppliers' responsibility to demonstrate that the equipment they supply is physically safe, that the safety implications of using the equipment are clear and that its failure behavior is understood. For COTS (Custom of the shelf) however, this might cause some problems as this is not specifically developed for safety-related applications.

The procurer should make clear the whether the intended applications are safety-related and, if this is not done, the procurer should request such information

2. In the event of failure, the PES shall remain in or revert to the least hazardous condition.

The main focus of this principle is how the PES handles the possible failures in which the PES ceases to provide the required functions. There might be different reasons as to how these failures came about, however, in all of the situations it is desirable that the PES move to a defined state, in which the risks are minimal. In order for this to work, the failure scenarios, including their concomitant hazards, should experience a careful consideration. This should be done at all relevant levels. If a manual response is needed in order to achieve movement to a safe state, this should be clear to all users. This movement could also be done by automatic means.

3. The PES shall provide functions which meet the user needs.

The most important aspect of this principle is that it focuses on what the PES does, rather than how this is done. In this principle the user is not only the immediate operating personnel, it also includes all parties affected the PES in all or parts of its life cycle. Examples of users are ship owners, installation staff and the maintenance personnel. The needs of the users can be both implicit and explicit, and a clear means of demonstrating user acceptance should be available. As users have varying skills and abilities according to their age, size, culture, level of stress etc. the PES needs to provide functions which are designed to fit these. In order to achieve this, the characteristics of the users and their level of expertise in using the system will need to either be specified or assumed. The responsibility to define these functions lies in the hands of the owner. However, the responsibility to refine the descriptions of these functions and make calculations of the costs is the responsibility of the systems engineer. As a result the role of the systems engineer should be defined early in the life cycle.

4. Functions shall be appropriately allocated between users and PES.

The important point here is that careful consideration is needed when allocating the functions. Even though automation of some task is possible, it might not be desirable. Also it is important that the manual task is not just the ones left after all the others have been made automatic. The user should be able to feel that their job is a meaningful one. The manual task should have special attention to safety-related function, and how they perform under stress. A hazard analysis might be used to determine which tasks should be manual and which should be automatic. The functions should be balanced so that they perform well-balanced tasks that address the issues of physical workload and mental workload. That means that the users should not have too many things to do or too much to think about.

5. The PES shall be tolerant of faults and input errors.

The important point of this principle is the problems that could occur within the PES, problems in which the PES is still able to provide some or all of the required functions. However, if there are problems of catastrophic proportions the second principle is more relevant. Fault tolerance is the ability to provide or maintain the required functions in the presence of a specified fault condition. This includes both user mistakes and errors in data from other systems that are connected to the PES and also environmental anomalies or even physical damage. The actions required could be automatic or manual. If it is manual, the user needs to be made aware that action is needed. In fact they should be made aware of the mistakes, even in situations where the PES has already corrected the error. It is necessary that particular care should be taken on order to ensure that safety-related functions have adequate independence, this need to be done in order to ensure that protective functions or general control functions with dangerous failure modes are affected by failures in other functions that experience failures. Ways to achieve this are through physical separation of equipment, the use of diverse technologies etc.

6. *The PES shall maintain specified levels of accuracy, timeliness and resource utilization when used under specified operational and environmental conditions.*

This principle focuses on the performance of the PES, and how it achieves its functions. The key aspects include the following:

- Specified levels: the meaning of the performance requirements should be understood by all parties, the means to achieve this is through documented definitions of both the levels and the tolerances that are to be achieved. Examples of these are global targets.
- Specified operational and environmental conditions: this should also be commonly understood. Maintain: the performance levels should be achieved for both the service life of the PES and for the changes in the prevailing conditions.

7. *Unauthorized access to the PES shall be prevented.*

A good overview of the security threats is needed in order to get a thorough understanding of the situations that could occur. The countermeasures that are to be implemented, either physical or procedural, need to be effective. Accidental and malicious operation of the PES are typical issues that needs to be addressed, one also need to address the ability to alter data or even programs. However, in marine systems the software may not be accessible to the crew, and the threats discussed above may even arise from external systems that are connected to the PES, and not caused just by the direct operator or user. Even when the hardware is the cause of the problems appropriate actions should take place, such as modifications or reconfiguration of the PES. Depending on whether the PES is high- or low-risk, a range of measures should be available to use as necessary. The key aspect is whether the user has permission or not, this can be implemented or checked through the use of passwords.

8. *The PES shall be acceptable to the user and support effective and efficient operation under specified conditions.*

Whether or not the PES is actually operable should be tested by representative users. They should test the usability of the systems through performing realistic tasks in a context of evaluation, this evaluation should resemble the real context of use of the PES. For PES used in safety-related operations, quantitative measurements of user performance on key tasks in the exact context of use are recommended. The level of assurance of usability can be determined from the risks associated with the total system. For low-risk PES an assessment provided by user representatives or usability experts might be enough. In this scenario they might check a standard list of usability criteria against the PES. When measuring the usability there are three broad classes of subjective or objective measurements that are required: effectiveness, efficiency and acceptability. In practice COTS present a particular problem, as the user trials used when they were developed, might have been done with users with different experience and training. Claims of usability for COTS should therefore be treated with caution.

9. *The operation of the PES shall be consistent and shall correspond to user expectations of the underlying process.*

Through their knowledge of how the ship operates, the users of the PES might have certain expectations of how the PES will assist them. When the PES meets these expectations they will work more effectively and also make fewer errors. However, the lack of situational awareness is the most significant factor in human error. If the PES match the user expectations with its displays of information and dialogue with the systems give the highest degree of situational awareness. The system should provide the user with knowledge of what its doing, what it is going to do, and explain the relationship between input and output. It should be noted that all of these aspects cover different aspects of situational awareness, and should therefore be addressed separately. An important issue is that the layout should behave and also to a certain degree look the same way both within and across systems. This ensures that the user does not get confused.

When the system is in the development phase the developers should take special care that the general ergonomics standards and specific project style guides are followed.

This is important in order for the look and feel of the interface to be consistent with other systems. This is also important for the functions of the system. Inconsistencies should be avoided in order to reduce learning efforts and it also avoids user errors that arise from misinterpretation of the information or the performance of a command sequence from one system to the other.

10. The interaction between the PES and the user shall be controllable by the user.

The fact that user of marine applications inevitably differ in background, training and their general ability to use PES. When designing the PES these differences should be taken into consideration. If the users find the PES inflexible or hard to use chances are that they will be hesitant to use it. In order to aid the controllability that the users want, the PES consoles should incorporate ergonomic features such as adequate physical space for movement. The users should also not be allowed to customize the set-up in a way that jeopardizes the safe operation of the ship.

11. The PES shall support proper installation and maintenance, including repair and modification.

The competence of the crew to perform maintenance and repair on-board the ship is an issue that needs careful attention. They should be aware of which components they can repair themselves and which need special attention by the supplier's service staff. The interfaces between the different modules should be well documented.

12. All PES life cycle activities shall be planned and structured in a systematic manner.

The life cycle often includes the following activities: requirements definition and analysis, design, implementation, integration, verification, transition to use, validation, operation, maintenance and decommissioning. In addition service activities should be considered, these may include quality assurance, planning functions, configuration management and independent assessments. This principle ensures that the other life cycle principles are applicable to all the organizations that are concerned with the dependability of the PES. These organizations include the owner, the ship operator and the yard, in addition to the PES supplier. They will all need to consider their responsibilities and they should demonstrate a systematic, planned approach to selected activities.

13. The required level of safety shall be realized by appropriate activities throughout the lifecycle.

Hazards should be identified, the risks that are associated to them should be assessed and necessary risk reduction measures should be taken to achieve an acceptable safety level. This should take into consideration the particular technology, functions and the context of use of the PES. The safety level should be justified through documentation of the results of analysis, calculations, expert consensus, phase verification activities and validation tests. If the PES is a high-risk application, the need to separate design, verification and validation responsibilities is important. The hazard and risk management description should be maintained throughout the life cycle.

14. Human-centered activities shall be employed throughout the life cycle.

The development of the PES needs to be user-centered, this process should start early and it should receive continued focus throughout its life. Feedback should also be provided throughout the life-cycle to ensure that the system is performing according to the users and developers expectations and also to check for problems which affects the efficiency, effectiveness or health and safety of the users. However it is important to ensure that the feedback comes as directly from the users of the PES as possible. In addition the developers should take account of the user's viewpoint when they are analyzing the needs for a PES and also during the development of a PES.

15. Verification and validation activities shall be employed throughout the life cycle.

The verification process is particularly important for the software part of the system. There is a diversity of methods that could be used for this process. Dynamic execution, like testing is universally applied, however this still means that only a small subset of the possible paths through the software is tested. In order to get further knowledge of the correctness of the software one could apply static techniques at a low level. The criteria for success should be made clear for all verifications.

When the PES is in operation the usability requirements may change if there is a new crew or the training the crew gets is changed. In order to deal with this, there is a need to reassess the level of usability.

16. *All parties involved in the life cycle activities shall have and use a quality management system.*

A quality management system plays an important part in providing assurance that specific requirements actually have been met. Systematic errors, either in the software or in the hardware, both during design and manufacturing, are minimized to an acceptable level through activities managed by the use of this quality management system.

17. *Existing requirements for marine systems shall be taken into account throughout the life cycle.*

Seeing that a range of requirements can apply to any marine PES it should be demonstrated which standards, regulative or legislative requirements are to be met by a particular PES. These should be traceable and whether or not conformance is required should be clearly stated.

18. *Suitable documentation shall be produced to ensure that all PES life cycle activities can be performed effectively.*

In the documentation for the PES each phase of development should be clearly stated by both an enter remark and in conclusion an exit remark. This remark should take the form of criteria that need to be met in order to move further. The documentation should also clearly state how the entry/exit criteria were fulfilled by including functional, operational, safety and quality requirements. For high-risk PES it is particularly important to clearly state clear traceability between the different documents that are a part of the documentation.

19. *Persons who have responsibilities for any life cycle activities shall be competent to discharge those responsibilities.*

The most important point of this principle is that no one should be required to work outside of their competence range or level. Personnel should be able to meet their assigned responsibilities and their competence should be demonstrated through appropriate selection, education, training, and/or experience. The responsibilities of key roles in the PES should be clearly displayed. If dealing with a high-risk PES the level of competence should understandably be higher than when dealing with a lower-level of risk PES.

20. The PES configuration shall be identified and controlled throughout the life cycle.

The basic requirement is to be clear on which software components comprise the PES and which specific versions are relevant to a given installation or build.

7.5 Summary

This chapter described the Atomos IV regulation and the ISO 17894 standard, which was a result of the Atomos regulation. Both of these are examples of efforts to improve the level of safety in the maritime industry. I described the parts relevant to the design of user interfaces in particular. The Atomos regulation tries to develop maritime safety and efficiency by combining evaluation of user needs with the development of new technology. The ISO 17894 standard provides general principles for the development and use of programmable electronic systems in marine applications.

Chapter 8 E-navigation

E-navigation is a proposal submitted to the 81st session of the Maritime Safety Committee at IMO headquarters in May of 2006. The proposal was submitted by Japan, Marshall Islands, the Netherlands, Norway, Singapore, the United Kingdom and the United States.

The proposal is relevant to my thesis because it represents a newly made effort to improve the level of safety in the industry. However, as it is no more than a proposal at present time it is only presented in short in the thesis. The e-navigation is also one of the issues dealt with in the initial questionnaire.

8.1 <u>The proposal</u>

In the e- navigation proposal the submitters propose that a new item should be added to the work program of the Sub Committee on Safety of Navigation and Radio communications and Search and Rescue on the Development of an E-Navigation Strategy [28]. The purpose of the proposal is to develop a vision for the handling of new navigational tools as well as the utilization of the tools that already exist. One particularly needs to focus on electronic tools, and this should be done in a holistic and systematic manner. Ideally E-navigation will help reduce navigational accidents, errors and failures, this will be done by developing standards for an accurate and cost-efficient system which will make a major contribution to the IMO's (International Maritime Organization) agenda of "safe, secure and efficient shipping on clean oceans".

In the submission the authors propose that IMO should develop a broad strategy for incorporating the use of new technologies in a structured way to ensure that their use is compliant with the various electronic navigational and communication technologies and services that are already available. In the end this submission wants an overarching accurate, secure and cost-effective system, with the potential to provide global coverage for vessels of all sizes. However the industry, as it is today, needs to make adjustments for this to be feasible. One needs to make modifications to working methods as well as navigational tools, such as charts, bridge display equipment, and electronic aids to navigation, communications and shore infrastructure. However, seeing that this is only a proposal, it is difficult to be precise about the full extent of the changes that one might have to make to fully deliver the vision.

In order for the captain of a vessel, and other responsible parties of the safety of shipping ashore, qualified to make good decisions, they need to be equipped with modern tools that makes marine navigation and communications reliable, less error prone especially of errors that lead to a potential loss of life, injury, environmental damage and undue commercial costs. There are several technologies available or in development that can aid the master and those ashore with the necessary information they require to make the right decisions at crucial stages. These technologies include electronic navigational, communication services such as Automatic Identification System (AIS), Electronic Chart Display and Information Systems (ECDIS) and radio navigation, among others. In addition to reducing navigational errors and failures, these technologies may also deliver benefits in other areas. Examples of such areas include search and rescue, pollution incident response, security and the protection of critical marine resources. The core objective of E-navigation is increased safety at sea, this will benefit States, ship-owners and seafarers substantially and the benefits are expected to arise with the increased safety. The main problem, according to the authors of the e-navigation proposal, with all of these technologies is that if they remain uncoordinated, with the lack of standardization, like today, there is a risk that the future development of the global shipping industry will be suffering, due to the before mentioned lack of standardization both on board and on land, there will be an incompatibility between vessels, and an increased as well as unnecessary level of complexity. At this point in time there exists no adequate industry standards, there has been made efforts, which have led to the development of standards for individual electronic navigational technologies. However, no single institution has taken it upon them to develop a comprehensive vision for E-navigation, for this to be done one needs to manage the buy-in from all the various key stakeholders, this needs to be done in such a way so it promotes the constructive development and standardization. The submitters of the proposition feel that IMO should serve as the appropriate body, as it is the only international body, capable of managing a program of this magnitude. The involvement of IHO, IALA, IEC and ICU will also be needed in order to realize some essential components. Even today ship-owners and operators spend significant amounts of money in order to make marine navigation easier. The strategy that E-navigation suggests would enable the industry to benefit from reducing these costs in the long-term aspect. The co-sponsors of the submission are convinced that if no action is taken soon, the disadvantages of pursuing uncoordinated individual technologies will outweigh the potential benefits that they could deliver. However, the co-sponsors also recognize that a full analysis of costs is needed, and the added administrative burden will involve a significant cost.

8.2 Summary

This chapter described the e-navigation proposal. This is an effort from the maritime industry to improve safety. The purpose of the proposal is to develop a vision for the handling of new navigational tools as well as the utilization of the tools that already exist. One particularly needs to focus on electronic tools, and this should be done in a holistic and systematic manner. Ideally E-navigation will help reduce navigational accidents, errors and failures, this will be done by developing standards for an accurate and cost-efficient system which will make a major contribution to the IMO's (International Maritime Organization) agenda of "safe, secure and efficient shipping on clean oceans".

PART IV: THE SURVEY AND THE QUESTIONNAIRE

Chapter 9 Developing the questionnaire

As the maritime industry is an industry that I was not familiar with at all prior to my work with the thesis, I naturally had to start with a lot of reading. However, sending out a questionnaire was defined as a fixed goal early on. I got the names of the recipients of the questionnaire from my advisor. He, in turn, chose these particular names from the participants of a project that he is currently involved with. I also received help from another employee at DNV. I got in contact with him through my work with the thesis when he helped me accessing some of the background information that I have used. He sent me addresses to recipients he thought would be able to answer the questionnaire. All in all, this amounted to 17 recipients. They are equipment suppliers, classification authorities, shipbuilders, one from a research institute and one who did not disclose his/her workplace.

9.1 How the questionnaire was made

In order to make a good questionnaire, I started with an extensive literature study. This was necessary when making both of the questionnaires, the initial questionnaire and the follow-up questionnaire. In order to achieve this, I had to read up on several standards, regulations etc, as described in the thesis. I wanted to make to-the-point questions that would supply me with all the information that I needed. I also had to read about how to make a good questionnaire, or survey, information which I have described earlier in this method chapter. There are other ways of gathering information that I could have chosen. Among them are field studies. However, as I had little experience with the topic, and wanted information in general about the safety in the maritime industry, a questionnaire felt like the best way to do it. I could have chosen to do a field study, if I had done this, I would have needed to find an appropriate place to study the participants, and maybe use face-to-face interviews of at least some of the participants. There are no apparent reasons why this would not have been a good way of doing it. However, I chose to conduct a thorough literature study, followed by the making of a questionnaire. I felt that I could get equally good information, if not better if I worked hard and developed a good questionnaire. Also, it was the question of where I should have conducted the field study, I probably could have received some help with this either from my advisor, or the employee at DNV, but conducting a survey seemed like a better way to go. The fact that I wanted answers from all parts of the industry also mattered.

The first decision that I needed to make regarding the questionnaire was to what kind of questionnaire I should choose. The different types of questionnaires are described earlier in the chapter.

There is probably no right or wrong answer to what method is the best, however I chose to conduct a self-completion questionnaire. I contemplated conducting a telephone interview, this was rejected because of the following reasons:

- The recipients of my questionnaire were presumed to be very busy, which would make it hard to conduct either a face-to-face interview or a telephone interview.
- Also, as the recipients are at a wide range of destinations both in Norway and other countries, a face-to-face interview would involve a lot of traveling.

However, I decided that perhaps a follow-up interview could be conducted with the use of a telephone interview. When it came to the making of the follow-up questionnaire, I initially thought that I would make it for a smaller proportion of the recipients. However, as the initial questionnaire did not shed enough light on the questions of user interface. I decided that the best would be if all of the recipients received this as well. This decision meant that once again a telephone interview was ruled out, for the same reasons as with the initial questionnaire.

The reason why I chose to do a self-completion questionnaire is that I feel that they are less importunate than the other types of questionnaires. I feel that this gives the respondents the time and opportunity to answer it on their own terms. This would perhaps mean that the answer rate could potentially be higher than if I put more pressure on the respondents. There are two main ways in which I could send out the questionnaire if I wanted to have a self-completion questionnaire. I could send it out via post, or I could do it by e-mail. The way I chose to do it was that I made a questionnaire through an online tool, and sent the link to the questionnaire in an e-mail that I sent out to the respondents. Also, the self-completion questionnaire allows for anonymity, an important issue, as explained previously. An example is the question which concerns the respondents' feelings towards the safety in their own organization. Although textbooks state that self-completion questionnaires have a low response rate, as mentioned previously, this was not a problem in the case of the first questionnaire. 14 out of the 17 that received the questionnaire answered. However, this was a problem with the follow-up questionnaire, where only four out of the 17 recipients chose to respond.

Theory that I have used to develop the questionnaire, [2] emphasizes that the questionnaire should be nice and inviting to look at, I tried to use this suggestion in my own questionnaire. It is also suggested that you should number the questions, which I did, and I also allowed for enough open space in the open-ended questions. Furthermore I have included a 'thank you note' at the end of my questionnaire. I wanted to recognize that the respondents have donated their time and efforts to answer my questions. I have also included a note on how the respondents can learn more about my research and the results that I achieve.

9.2 Use of the checklist from chapter 2.3.2 to avoid problems in wording

1. *Keep the language simple. Avoid jargon. Seek simplicity but avoid being condescending.*
2. *Keep questions short. Long and complex questions are difficult to understand.*
3. *Avoid double-barreled questions. Double-barreled questions ask two questions at once. Split them into separate questions.*
4. *Avoid leading questions. Leading questions encourage a particular answer.*
5. *Avoid questions in the negative. Negative framed questions are difficult to understand; particularly when you are asked to agree or disagree.*
6. *Ask questions only where respondents are likely to have the knowledge needed to answer.*

7. *Try to ensure that the questions mean the same thing to all respondents. Meanings and terms used may vary for different age groups, regions etc.*
8. *Avoid a prestige bias. This occurs when a view is linked with a prestigious person before asking the respondent's view.*
9. *Remove ambiguity. Take great care with the sentence structure.*
10. *Avoid direct questions on sensitive topics (in interview situations). Several indirect strategies are possible.*
11. *Ensure the question's frame of reference is clear. When asking for frequency of an event, specify the time period.*
12. *Avoid creating opinions. Respondents don't necessarily hold opinions on topics. Allow a 'no opinion' alternative.*
13. *Use personal wording if you want the respondent's own feelings, etc. impersonal wording gives the perception of other people's attitudes (use it if that is what you're after).*
14. *Avoid unnecessary or objectionable detail. It is unlikely that you will want precise income or age; use income or age groupings.*
15. *Avoid prior alternatives. Give the substance of the question first, then the alternatives. Not the reverse.*
16. *Avoid producing response sets (particularly in interview situations). With 'agree/disagree' questions, some people tend to agree regardless of their real opinion or provide answers making themselves look good, e.g. inflate their income or decrease their alcohol consumption. Seek to put people at their ease and avoid giving the impression that some answers are normal or unusual.*

Table 9-2 Checklist to help avoid problems in question wording. From Robson [2]

I tried to keep the language simple and the questions short, I also made sure that they were concise. The checklist states that you should avoid leading and negative questions, I made sure that none of my questions came across as that. It is important that the questions mean the same to me as the respondents, I made sure of this by testing them on others before sending them out. When I asked for the respondents' opinion on something, I always allowed for them not having an opinion by including a 'no opinion' alternative. When asking multiple-choice question, I always gave the substance of the question first, before giving the alternatives to chose from.

9.3 The content of the questionnaire

The initial questionnaire consisted of 32 questions, 18 are multiple choice questions while 14 require free text answers. I estimated that they should use 10-30 minutes to complete the questionnaire, depending on the level of participation, i.e. to which extent they choose to answer the free text questions. The questions in the questionnaire dealt with several topics that I wanted to know more about. First, and foremost, I wanted to know how the respondents felt about the safety level in the industry in general, and also in their own company or organization. I had a large section of questions that dealt with ATOMOS and the SOLAS regulation. I also wanted more information about whether or not the ISO 17894 and the E-navigation proposal are known in the industry. They were supposed to guide the industry towards better safety, but I wanted to know if they were actually known. I expected that a few of the propositions and proposal that I had heard about was not known in the industry, so I decided to include a few questions were the respondents themselves could explain which propositions and proposals they were familiar with, and what they thought about them. This also included questions about how they felt the safety issue should be addressed, and whether or not the national governments should have something to say in the matter. All of the results may be examined in the "Analysis and discussion of the questionnaire" chapter.

The follow-up questionnaire consists of 33 questions, where five are multiple choice type of questions, eight are yes or no type questions and 20 require free text answers. The recipients will need 10-30 minutes to complete the questionnaire, depending on their level of participation. The first questionnaire did not go as deeply into the user interface and safety issue as I wanted it to. The follow-up questionnaire has a lot of questions concerning the user interface and safety more specifically. As ISO 11064 is an important part of my thesis I wanted to see if the recipients had any knowledge about this as well. The ISO 11064 standard concerns design of control centers, like the ones at the bridge of the ships. However, unlike with the first questionnaire I anticipated that this might not be very familiar to the recipients as it does not concern ships in specific. Still, it is a very important standard that they should be familiar with. The follow-up questionnaire also consisted of a lot of questions dealing with training, alarms in the systems and error and emergency handling. The results are discussed in the Analysis and discussion of the questionnaire chapter.

When I felt that I had done all that I could do with the questionnaire, I handed it over to my advisor so that he could have a look at it. He in turn handed it over to a doctorate student of his who also examined it.

9.4 Summary

This chapter took the theories from chapter 2 and described how they was used in practice when I made my questionnaire and survey. I used a checklist to avoid misunderstandings due to the wording of the questions. I also described the background for decisions regarding the look of the questionnaire. I also described that I tried to keep the questions short and easy to understand, while giving the questionnaire an appealing look.

Chapter 10 The initial questionnaire

I will refer to the respondent as he when describing their answers in discussing both the questionnaires. I do not know the respondents sex, but it simplifies reading and writing, when doing it this way.

10.1 Analyzing the answers to the questionnaire

When the results of the questionnaire started to come in, I created tables with the raw material. With the basis in the results, I made a summary of the results, so they are easy reachable if someone wants to take a quick look at them. The most prominent piece of work that is based in the results of the questionnaire is my analysis of the results.

When analyzing the result of the questionnaire, I decided that I wanted to do this first within the group, i.e. equipment suppliers, classification authority. When I had done that I also wanted to discuss the results across groups.

The groups that I discussed and analyzed within are:

- Classification authority
- Equipment suppliers
- A research institute
- Shipbuilding yards
- Other

The reason why I wanted to analyze within the groups is that I wanted to see if there were any similarities in the way the respondents answered. I wanted to find out if the respondents within the same group felt the same way as the others in the same group. I also took a closer look at whether or not there was a pattern to the way the different respondent's answered. This also lead to me taking a closer look at whether or not there were any similarities in the way the respondents within the group answered. It was perhaps equally interesting to see if there were any similarities in the answers given by respondents across the groups, and this is thoroughly analyzed in the analysis chapter as well.

This chapter deals with the initial questionnaire. This questionnaire deals with safety in general in the maritime industry. It also deals with how much knowledge the members of the industry have of official standards and propositions to improve the level of safety.

10.2 Analysis and discussion of my questionnaire

10.2.1 What is this questionnaire about?

As a part of my master thesis I sent out a questionnaire to a group of people in the maritime industry, these represent shipbuilding yards, equipment suppliers and class authorities. My main interest in the thesis is the user interfaces, e.g. the human-machine-interface, and how this may affect safety. With user-interface, I specifically mean the screens, and the layout of the control room/bridge, and how the users are able to relate to this.

I made a questionnaire to get a better understanding of the issues related to how the safety issue is handled in practice, and also what thoughts people inside the industry can share with me regarding it. The questionnaire consists of 32 questions, where 18 are multiple choice type of questions and 14 require free text answers.

The questionnaire was sent to 17 recipients in all. From these 17 recipients I received 14 answers, which I consider a good answering rate.

10.2.2 Background information about the participants

In the questionnaires introduction part I asked the participants about their organizational role. The recipients included eight equipment suppliers, two from shipbuilding yards, two from a classification authority and two who did not find their occupation in the categories that I stated. However, one of these works at a research institute. This is known to me because his/her e-mail address reveals it. He still appears in the “None of the mentioned” category in figure 9-14. This figure shows the distribution of the recipients in the different lines of work.

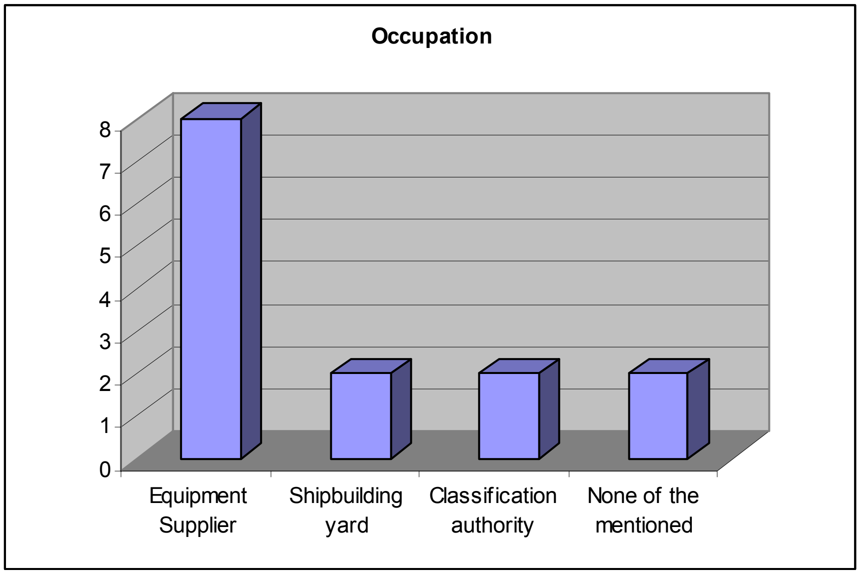

Figure 9-15 Occupation

Twelve of the recipients were from Norway, one is from Finland one is from Germany.

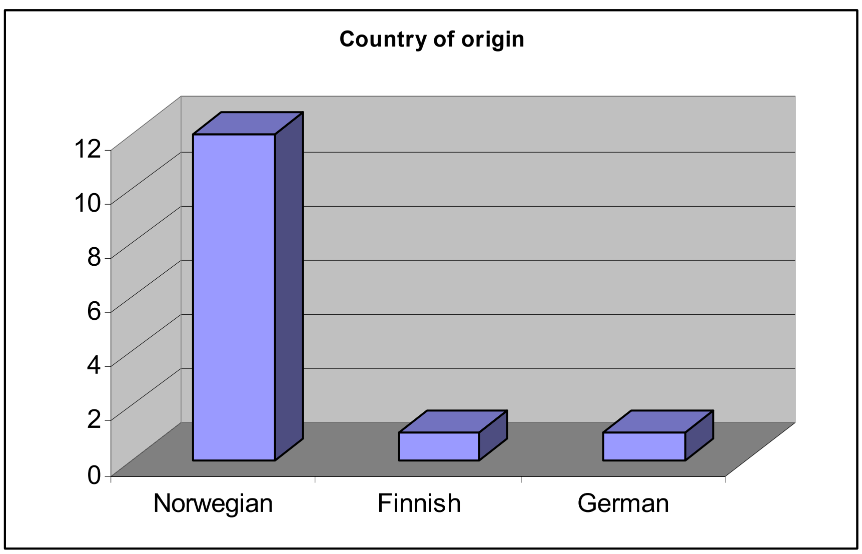

Figure 9-16 Country of origin.

I sent out my questionnaire in two recipient-groups, the first group received their questionnaire a month before the next group. The reason for this is that I did not have the names for the second group until later. The first group of names was given to me by my advisor, while the other group of names was given to me by someone who works at the classification authority.

My advisor works at DNV in addition to his job at NTNU. At DNV he is participating in a project called SMICT (Safe Maritime ICT), the names given by him are participants of this project. After sending the questionnaire out the first time I sent a reminder of the questionnaire to each of the groups three times. As previously mentioned this resulted in 14 answers.

The findings from the questionnaire offer insight into how practitioners feel about safety, and some, for me, surprising findings on what they have not heard about. When I set out to make this questionnaire I had a major focus on Atomos IV and the SOLAS regulation [22], and many of my questions were directly related to these efforts. Atomos IV and the SOLAS regulation are EU projects. However, when I received my answers it became apparent that close to none of the recipients had heard of these efforts, and therefore had no experience with their use in practice. The results were similar for the equipment suppliers and the shipbuilding yards. This is not surprising as they were all answering questions regarding safety, a topic that is relatively objective for both the suppliers and the ones assembling it. However, the answers from the respondents at a classification authority were also quite similar, but on quite a few of the questions they offered more insight as these might be topics they are more familiar with.

10.3 What information did I get from the questionnaire?

In this part of the thesis I will go through the questions of the questionnaire and discuss which results they gave.

10.3.1 What feelings do the respondents have towards safety?

This section was divided into eight sub-questions. These are, respectively:

1. Personal information
2. Safety handling in the industry and company

3. Propositions and procedures
4. The position of the national governments
5. ATOMOS
6. Addressing the safety issue
7. The e-navigation proposal
8. ISO 17894

10.3.2 The safety in the respondents own company or organization

One of my first questions was a rather personal question. I wanted to start off by finding out what the recipients themselves thought of the general safety level in the organization or company that they work for.

Seven of them answered that the level of safety in their company is *good*, while two even thought that the level of safety is *very good*. Four find it *satisfying*, and one does not have an opinion. If we take a closer look at which of the respondents answered what, we see that five of the respondents that answered *good* works as equipments suppliers and one of the equipment suppliers think that it is *very good*. However, two of the equipment suppliers only find the safety to be *satisfying*. This can mean that the equipment suppliers in general find the level of safety to be good, as so many of them chose this alternative as their answer. However, it is hard to conclude whether the reason for this is that this part of the industry actually takes care to mind safety or this result comes because the equipment suppliers just do not think about it as much. Further, I have two respondents from shipbuilding yards, one of them thinks that the level of safety at his company is *very good*. However, the other respondent from a shipbuilding yard finds the level only to be *satisfying*. Fortunately, these two respondents work at two different shipbuilding yards, which means that there is no apparent disagreement about the safety level within the same organization. However, one could deduct that the respondent who answered very good works at a company that focuses on the safety issue. The respondents from the classification authority both find the level of safety in their company to be good. It is not easy too say why they are in such accordance, but one reason could be that it is because a classification authority is likely to have safety high up on their agenda. This is because safety is an important part of what the classification authorities' deals with.

Figure 9-17 Level of safety.

When the participants were asked to elaborate on the answers they gave when asked what they thought about the level of safety in their organization, I received varying answers.

Most of the respondents took the time to answer this free text answer. When looking at the answers from the equipment suppliers it is evident that most of them pointed out regulations as an important part of their safety handling. Several also mentioned that safety has a high priority in the organization, and is therefore taken very seriously. However, as one equipment supplier points out, there is a potential for improvement of procedures and practices that concerns safety issues. Another respondent point out that close cooperation with classification authorities aids their safety handling. The easiest way to do this seems to be through understanding and implementing rules from class and authorities, as this is pointed out by several of the equipment suppliers. Two of the respondents that are equipment suppliers even mention testing as an important way of ensuring a certain level of safety. When doing their testing they do both system testing and internal testing. Also, the respondent says, they take into account all failure modes. Disappointingly, one equipment supplier points out that their only concern when it comes to the safety issue is that they should satisfy the requirements set by IMO (International Maritime Organization). However, this might be linked with his/her answer to the question regarding the level of safety in his/her organization, to which the respondent says that it is satisfying. One should think that this means that at least they are aware of the problem. The results of all of their answers seem to be that the responsibility lies in the hands of the classification authorities.

The answer given to the same question by the classification authority respondents is: That it is handled by implementing class rules, IMO requirements, IEC safety standards and working with developing and implementing new standards, rules and regulations. This answer bears a striking resemblance to the answers given by the equipment suppliers.

When the respondents working at the shipbuilding yard gave their answers they were a bit different from the other answers, one pointed out that safety issues always are classified as priority one. This is a good sign, it is worth mentioning that this respondent was the same that said that the level of safety in his organization is very good. The other answer is fortunately as positive as the other one, as he answers that some people are looking at their own system, but this is not necessarily enough, as you need to look over all systems, as they may influence each other. However, as this respondent only finds the level in his/her organization satisfying, their focus might prove to be lacking, at least in their own eyes. All in all, the respondents seem to be focusing on safety both themselves and within the organization, regardless of their affiliation.

10.3.3 The safety in the maritime industry in general

What might prove to be more interesting is when you compare the respondents views of the level of safety in their own organization to their views of the level safety in the maritime industry in general. An overview of the results can be seen in figure 9-17.

Figure 9-18 Safety in the shipping industry.

Interestingly, none of the respondents answered *very good* to this question, although two actually answered that when asked about their own organization. This could mean that the safety level is actually lower in the industry as a whole. However, it could also mean that the respondents are influenced by their "origin", i.e., the companies they work for, when answering the question. It is easier to be negative about something when you have a more objective mind, than say, about your own organization. Another important aspect is that the respondents could be blaming others when issuing a verdict on the whole, while they think that their own contribution is more than satisfying.

When taking a closer look at who answered it is evident that the equipment suppliers have the most pessimistic opinion of the safety level in the industry, as four of them answered that the level is poor, while two did not have an opinion. The last two rated the level to be *good*. The respondents from the shipbuilding yard on the other hand have a somewhat brighter point of view, in coherence with their answers to the level in their own organization. One of them answered *good* while the other answered that it is *satisfying*. This is also in coherence with their answers, respectively, as the one who answered that the level in his/her organization was *very good*, answered *good* here, while the other respondent answered *satisfying* to both questions.

The respondent from the classification authority, who according to the last question is largely responsible for the safety in the industry, has an opinion as pessimistic as the equipment suppliers. Of the two respondents, one thought that the level of safety is *satisfying* while the other find the level of safety in the industry *poor*. This might be the most disquieting finding thus far. If the respondents from the part of the industry that the others look to for help are this negative, what does that say about the actual level of safety? However, as this questionnaire was answered by only two respondents from the classification authority one should be careful not to read too much into it. What is clear is that the general view of the safety in the industry is not good.

Once again the respondents where asked to elaborate their answers. This gave the respondents from the equipment suppliers who did not have an opinion the chance to explain why this is. One said that he or she did not have enough marine industry experience to answer this particular question, while the other points out that there are too big variations regarding location to answer. One equipment supplier points out the following: “Whether intentionally or not, it is possible for them to hide safety critical functions from outsiders. Problems regarding the hidden functions will only come to the surface when a certain situation occurs.” This has probably lead this individual to answer that the level of safety in the industry is poor. The general opinion of those who answered is that the level of safety in the maritime industry is poor. They have concerns regarding the competence regarding the interfaces, and the interfaces between all the different systems. Some also think that this is rooted in the economic issue, their concern is that the industry is not prepared to invest enough money to obtain the required safety level. It is also pointed out by one of the respondents, who works at a classification authority, that safety is mainly dependant on getting properly trained and qualified personnel who can ensure that the maintenance and operation of the ship is adequate. Furthermore, he supports the point just stated, that ship-owners need to have sufficient focus on having the budget to properly train the operators and to implement the ISM system.

I have made a follow-up questionnaire that tries to shed more light on issues like the training of operators. Special precautions need to be taken in order to prepare the operators to handle stressful situations with tense work conditions.

10.3.4 Efforts to improve the safety in the maritime industry

As stated in the introduction, the purpose of the questionnaire was to get information about how the people who actually work in the industry on a day to day basis think about the safety issue. One obvious question is therefore whether or not they have heard about any propositions to improve the safety in the maritime industry. When asked about this eleven of the fourteen respondents answered yes.

All but two of the equipment suppliers were familiar with such a proposition, which ia a good turnout, and also supports the hypothesis that the equipment suppliers focus on safety on a day to day basis. Surprisingly one of the employees at the classification authority was not familiar with any propositions. When making this questionnaire it was my firm belief that personnel working at places such as a classification authorities would be the most knowledgeable at least when it comes to the theories of safety. The reason for this is that they are the people that deal with propositions and regulations on a day to day basis. As previously mentioned I got the list of addresses from my advisor working on the SMICT project, and understandably quite a few of the respondents mentioned this as the proposition they were familiar with. Many of the respondents expect that efforts like these where the industry cooperates, will help them to end up with new and better rules. The equipment suppliers are the group that mentions the SMICT project most frequently. The respondents that work at shipbuilding yards mention two different aspects, one focuses on what actually happens when working at the shipyards. However, it is positive that he focuses on what is closest to him/her. What they actually do on some shipyards is that they have special safety at work documents that all the workers have to read. The other respondent from a shipbuilding yard focuses more on the task at hand in this questionnaire and says that they can participate at workshops both from the classes and the IEC (International Electro technical Commission) groups. The participant from a research institute says that propositions from IMO (International Maritime Organization) play an important part in this issue. IMO is continuously working on this with the help of standards organizations. The fact that so few propositions are mentioned can have several reasons, one being that since the respondents are participants in the SMICT project, these standards come first to mind. Another reason might be that the respondents just do not focus on such issues, which could be said to be the very foundation of safety. If this is the case, the path ahead seem pretty clear, more focus should be put on the propositions made.

Five of the seven that answered that they were not familiar with such procedures turned out to be equipment suppliers. As these are the same people supplying the industry with such information this could seem a bit disquieting. However, it is important to understand that there might be several reasons for this result. One of the reasons could be that they might have misunderstood the question. Also, they just might not know how it is done in practice, as they probably are not the people actually training the operators. Of those who answered yes, very few specific procedures are mentioned. Respondents have heard about various rules and regulations from classification societies and also government requirements. A few however, chose to write about some specific procedures. According to these respondents both ISM and ISO contribute to these questions. IDM code will require procedures for the most critical operations. They supply the industry with certifications that requires operations and procedures to be documented, implemented and maintained. This is an important contribution as it is much easier to handle problems and arising issues when you have documentation. Documentation simplifies the task of finding out what went wrong, or even what did not go wrong. Also, one respondent says that most critical ship systems have procedures, at least in the form of IMO performance standards. As mentioned previously IMO plays an important role in the safety handling in the industry and the fact that so many choose to include them in their answers could mean that their contributions are worthwhile.

10.4 Questions regarding the ATOMOS IV proposition

The next bulk of questions deals with the ATOMOS IV proposition and especially with whether or not the respondents are familiar with the proposition, and what they actually know about it. These principles has also been developed into a standard, described in this thesis, ISO 17894. The ATOMOS IV proposition is in fact the foundation for the ISO 17894 standard. And they are therefore nearly identical. I have asked the respondents whether or not they were familiar with the standard later on.

As mentioned earlier in this chapter I had high expectations for ATOMOS since this is one of the most prominent efforts to improve the safety level in the maritime industry. However, as becomes evident from the bar chart above, many had not even heard of ATMOS. In fact only two respondents could say that they had heard about it. ATOMOS was a huge part of not only my thesis, but the questions in the questionnaire, that there was so little knowledge about it was somewhat devastating. However, as one of the respondents pointed out in an e-mail, ATOMOS and Regulation V/15 was ready in 2002, but has not been put into use in any way that has any effect. Unfortunately, this means that the next five questions got little or no response.

However, to the question of the general opinion of ATOMOS, on of the respondents answer. He explains that according to rumors ATOMOS implemented some development principles in a Swedish ice-breaker, although unsuccessfully. Fortunately, it seems that ATOMOS had some hand fast positive repercussions as well, as some of the results from ATOMOS were adopted by the Lloyd's register. An example of such results being adopted is the design principles for Programmable Electronic equipment, an issue which is dealt with later in the questionnaire, and also in this thesis. Furthermore I wanted to know whether or not the respondents thought that the regulation and the safety issue should receive more attention. As most of the respondents were unfamiliar with the regulation, most of the answers were regarding the safety issue.

10.4.1 Should the safety issue receive more attention or not

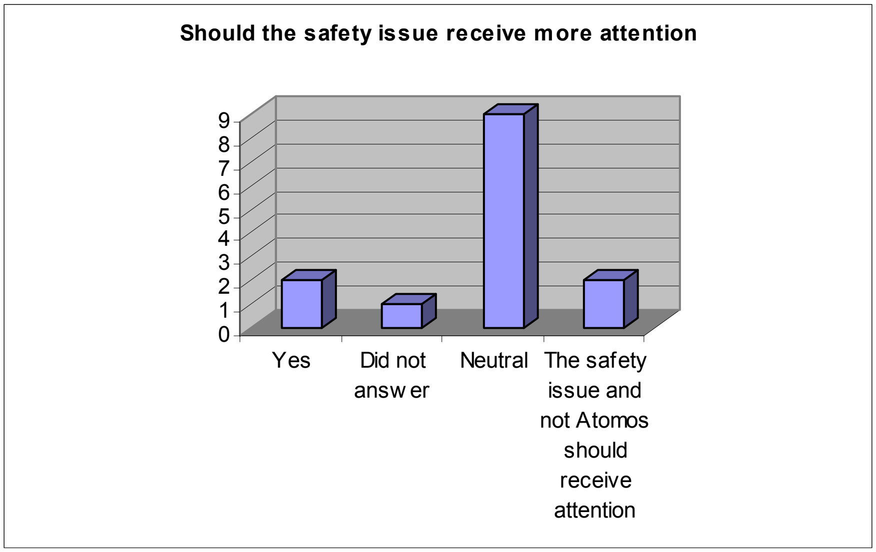

Figure 9-19 More attention to the safety issue.

As many as nine of the respondents answered that they were neutral to this question, however, as it was so closely linked to ATOMOS, that so many had no knowledge of, this could be the reason for the high degree of neutrality. Also, it is worth noticing that the neutral answer also includes the respondents who answered that they were not familiar, and by not familiar I suppose that they mean with ATOMOS.

Of the two that answered yes to this question one is an equipment supplier, while the other one that works at a classification authority. Also, one equipment supplier and the respondent from an undisclosed workplace, answered that the safety issue and not ATOMOS should receive attention. As there is so much uncertainty as to why the respondents answered what they did, no real conclusion can be drawn from their answers. The reason is probably that I did not anticipate ATOMOS to be so little known by most respondents. However, when the respondents were asked to elaborate their answers I did get some extra information. One of the respondents that works at a shipyard pointed out the following: “Safety is an important issue. We are at a good level in safety thinking now”. This is the same respondent that was very positive to the efforts being made to maintain a good safety level at his own company, and he was also positive about the level of safety in the industry in general. Another respondent stated that for both vendors and suppliers it was more important to focus on the safety than to focus on regulations. This person was the same one that answered that the safety issue and not ATOMOS should receive more attention, so this seems to be in coherence with each other. This person represents an equipment supplier. The third answer says the following: "IMO NAV has formed a correspondence group that among other things will look at the BRM (Bridge Resource Management) issues in conjunction with SOLAS V/15. People from ATOMOS are participating there and will bring their experience into the work. The draft standards will most likely be delivered to NAV 43 in July". Not surprisingly, the person who gave this answer actually had knowledge of ATOMOS, but he had never seen it in use. This person works at an undisclosed location, as his/her place of work unfortunately was not listed by me.

10.4.2 What role should the national governments take

Another question that I wanted answered was how the respondents felt about the involvement of national governments in the safety issue. Should they be involved more, less, or not at all?

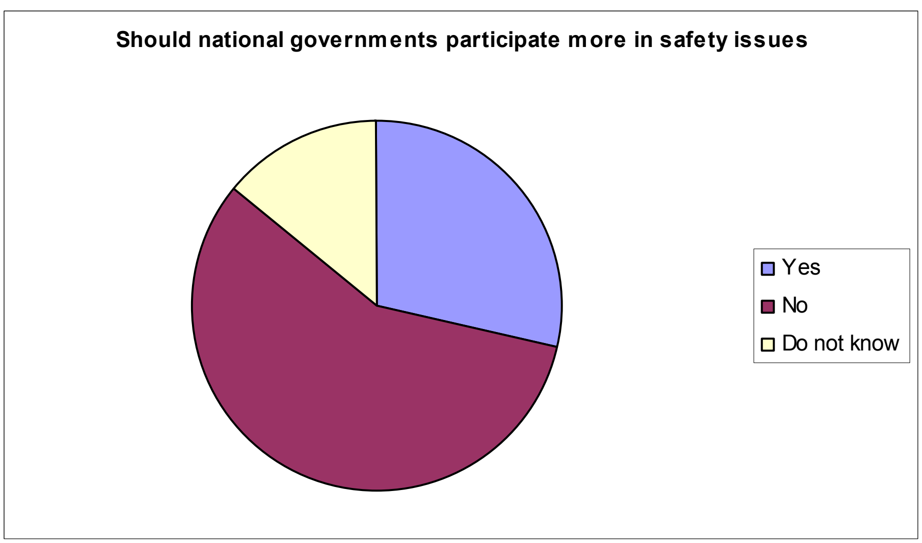

Figure 9-20 The participation of the national governments.

As you see from the pie chart, it seems that most of the respondents think no, but is there one group that feels stronger for this than the other? Of the two that answered *yes* to this question, both were equipments suppliers, however, as four of the equipment suppliers answered no, this says relatively little about them as a group. In fact the group that has the most *yes* answers compared to the amount of recipients is the group that answered *none of the above* to the question of which part of the industry they belong to. Unfortunately, this gives us no clue as to whether or not there is a certain part of the industry that supports this more than the others.

However, when looking towards the recipients that are negative towards the involvement of the national government we see that both of the respondents from a shipbuilding yard answer no, as well as both of the respondents from a classification authority. This result might indicate that these groups/parts of the industry feel more strongly against the participation of national governments. Luckily, the next question gives us some clues as to why. One of the people who said *yes* represents an equipment supplier, he backed up his *yes* answer by saying the following: “This to guarantee the same rules for all”. There was one other equipment supplier who answered *yes*, he wanted the participation of the national government to be at least as much as today. This means that a majority of the equipment suppliers are negative to the participation of the national governments. Not all who said *no* chose to say why they feel this way, however, one of them points to the fact that this is an international task. Another feels that the level of participation today is at a good level, and in the future this level should be kept, rather than increase or decrease it. He also point out that the level of interaction today is “a healthy one”.

Two of the equipment suppliers did not know whether they were positive or negative towards the participation of the national governments. One of them states that there are both pros and cons of involvement with national governments so it is difficult to have an opinion. With regard to the people working at a shipbuilding yard they are both negative towards the involvement of the national government. Unfortunately, neither of them give a reason for their feelings, so little can be said as to why they feel the way they do.

Both the person working at a research institute and the person who works at an undisclosed place are positive towards the involvement of the national governments. It is pointed out that “Sjøfartsdirektoratet” is participating actively together with other parties, like DNV and the research institute. However, it looks as if “Sjøfartsdirektoratet” does not have enough resources to really follow up on this as one could wish for. This is interesting as the person from a research institute probably sees the situation a bit differently from the equipment supplier as they have different roles in the development process. Finally, we see that both persons working at the classification authority are negative towards involvement from national authorities. One of them points to IMO as the authority of choice for the maritime industry. While the other says the following: “Safety regulations need to be developed on an IMO level to avoid too many special requirements for different flags which will not benefit the industry”. It is interesting that both the people at the classification industry feel the same way and also that they both point towards IMO being the only real authority and alternative in this situation. As with the equipment suppliers and the people from a research institute and the undisclosed location, the people from the classification authorities see the situation from a different point of view than the others. While the equipment suppliers develop the different parts, actually used, the ones working at the classification authority might have a more theoretical approach towards the problem and situation. It is also interesting that many of the respondents, from different areas of the industry, point to the same reasons, whether they are positive or negative. However, it seems pretty clear that in the maritime industry as a whole they are negative towards more involvement from the national authorities.

10.4.3 The way the industry should address the safety issue

With respect to the issue of how the industry should address the safety issue there are some minor disagreements. As they were given several choices to answer in this question, rather than it being a free text question, the answers are somewhat similar. However, some of the respondents have included more choices than the others.

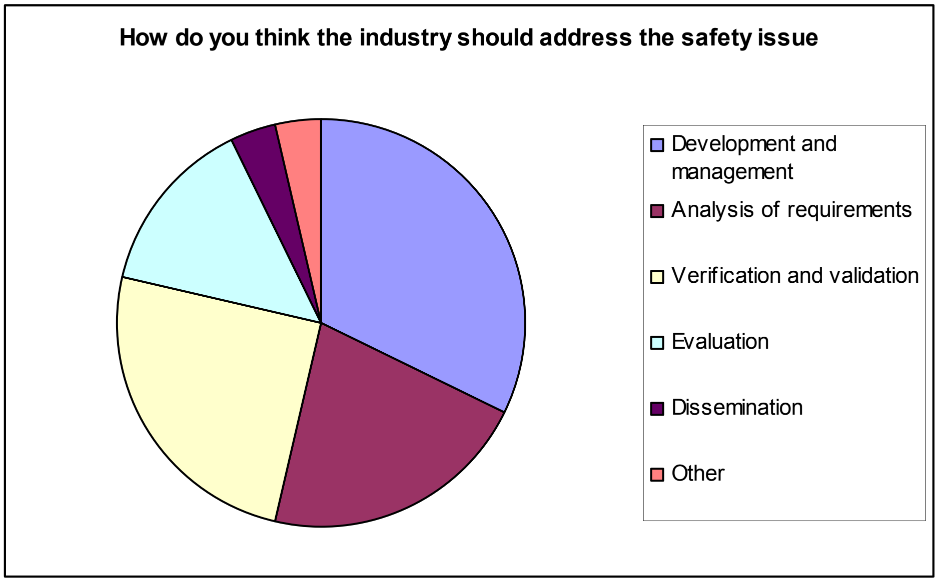

Figure 9-21 Addressing the safety issue.

The figure above gives an oversight of how the respondents answered. It is important to bear in mind that they all had the option of giving more than one answer to the question. It is interesting that development and management get most “votes”. As this is also the option on the top of the list, it is tempting to wonder whether this actually is the option that the respondents feel most passionate about, or if it is because it is the first option they see. It is also worth considering whether the two who gave development and management as their single answer understood that they could tick several of the option boxes to this question. However, I think we could safely assume that this is not the case.

All the equipment suppliers except for three mention verification and validation in their answers. This indicates that they as a group think this is an important issue that should be addressed. It is also interesting to notice that both respondents from the ship builders mention verification or validation, one even has it as his/her only answer.

Meanwhile none of the workers at classification authorities mention it and neither does the respondent from a research institute or the undisclosed workplace. This seems to be the biggest difference between the answers of the different groups. Development and management seems to be important for everyone regardless of which group they belong to. Analysis is another issue that seems to be more important to the equipment suppliers.

This might also be because this is a larger group than the others, and gives a clearer indication of the behavior of the group as a whole than the others. However, while five of the eight equipment suppliers include analysis of requirements in their answer, only one of the respondents from classifications authorities do so, together with one respondent from a research institute. Neither of the shipbuilders chooses to include analysis of requirement as an important part of addressing the safety issue. Reasons to why it is like this are discussed in the analysis of the next question. One of the equipment suppliers chooses to include all of the mentioned items in his answer. The reason he did this is as he says in his/her answer to the next question, that no approaches to improve safety issues can be ignored by the industry. This is a valid point as all of the items included in my list are important items of the checklist when developing new systems. Another equipment supplier, who in his/her answer included only analysis of requirements on his list, says the following: "It is important that the industry develops sufficient safety solutions and the solutions should be based on requirements". Clearly these two are on two extreme points, as one includes all items and the other only one. Fortunately, they both include the reason for their action. It seems as though one chose all, because safety is important, perhaps without reflecting too much on what they actually meant. The other assumed that as long as the requirements are followed, the system/solution will be safe. However, neither of these are a certain way to success, the most important issue is reflection over what is actually done. Only then will the items on the checklist make sense. In addition to the equipment supplier who only mentioned analysis of requirements as an important tool to safe solutions, another also stated the fact that developing according to requirements as a good way of achieving safe solutions/systems. In his/her item list this person also included development and management as an important item to remember. The last equipment supplier who chooses to answer this question mentions the presence of competent people when following up the systems and sub suppliers as important. In his/her checklist he included development and management as a way of addressing the safety issue.

Furthermore, one of the respondents from the classification authority says the following: "Safety issues needs evolution and updates to follow the industry development of new technology. The industry is challenging technical borders, systems are becoming more integrated and complicated, and maintenance, possibilities for emergency operation and education personnel is not following the development". It is clear that the respondent means that as the systems continually change, so should the way we address the safety issue. Everyone in the maritime industry should make an effort to follow the development and face the consequences that arises. The other respondent from a classification authority actually chose to answer *other,* from my checklist on how to address the safety issue. When elaborating on this, he says that implementation of existing standards and regulations, is the way to go. As mentioned above, both of the respondents from a shipbuilding yard, included verification and validation in their answers. One of them underlines this with the following statement: "The industry has to look to the regulations and to say, what is technical possible with the new technologies. Sometimes the words have to be changed. Then it is possible to get the same degree of safety, but the costs of the system will be much less". I suppose that what he means is that we can still look towards the older regulations for answers to the safety issue, although the wordings might have to be changed.

The respondent from a research institute also chose to answer this question, he said:" These issues should be addressed through IMO instruments and corresponding technical standards (from ISO and IEC in this case). Industry would then normally comply with these standards. IACS will also put in place requirements together with the individual class societies". It is worth repeating that he checked of development and management and analysis of requirements on my checklist. IMO (International Maritime Organization) gets mentioned in the respondents' answers pretty often. This is a good sign, as this shows that they are getting noticed by the actors in the industry.

10.4.4 What contributions are particularly noticed

When the respondents were asked whether there were any efforts in particular they wanted to point out, most of them declined to answer. However, one of the respondents took the opportunity to mention the IMO e-navigation proposal that I have described in my thesis. [28] I do not know where this respondent works. The respondent from a research institute repeated his/her previous answer, where he stated that issues of safety should be addressed through IMO instruments and corresponding technical standards. As we can see, IMO is again mentioned by two of the three who chose to answer the question. The third respondent who answered simply stated that there are just too many to mention.

The respondents were also asked to comment on how they feel about the contributions they mentioned in the previous answers. Depending on how they interpret the question, they commented the previous question, which, in fact was only answered by three, or they choose to interpret it as the last few questions. However they interpreted it, eight were neutral, while five were positive to these efforts. One did not answer.

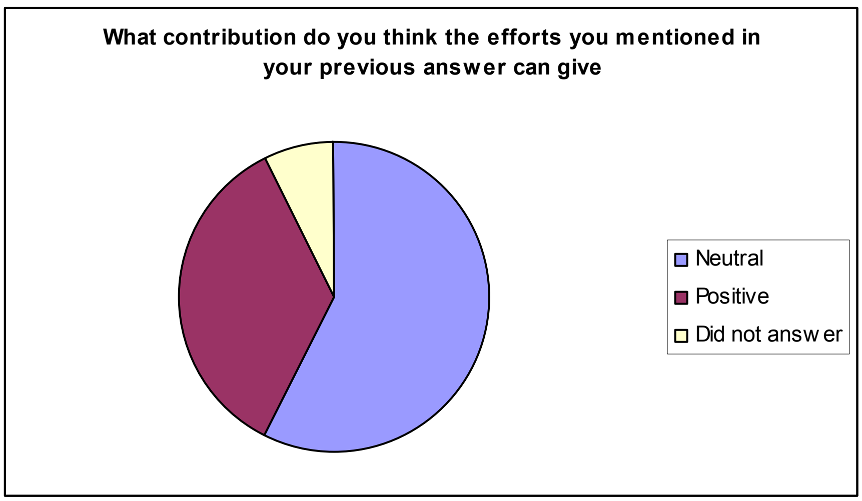

Figure 9-22 What contribution the efforts give.

All but one of the equipment suppliers was neutral to this question. Both of the respondents from shipbuilding yards were also neutral. The respondent from a research institute was also positive, and so was the respondent from an undisclosed workplace, together with both of the respondents from classification authorities. One of the equipment suppliers chose not to answer, this can be because he did not answer the previous question either.

As a conclusion to this bulk of questions the respondents were asked to mention any suggestions or thoughts they have regarding the subject of safety. Again, only three chose to answer the question at all. One of the respondents who answered works at a classification authority and he says the following: “Safe ships needs to be simple and intuitive to operate and maintain. ISM code is implemented and this has already improved operation of ships and ship management”. The issue he mentions here is a issue that I examine more closely in the follow-up questionnaire, namely the issue of how simple the systems are to operate and maintain. As mentioned in the ATOMOS part of the questionnaire many of the accidents in the maritime industry are a result of human error. Although this is a source of debate, as mentioned in the chapter about “Accidents due to poorly designed user interfaces”, chapter 6, it is indisputable that ships that are simple and intuitive to operate should be less prone to accidents. The respondent from a research institute mentions that more involvement from the industry in rule-making would be good. This is a good point, as it might be easier for the industry to actually maintain and follow the rules if they are a part of making them, rather than the rules being forced on them from the top. On respondent who works as an equipment supplier says that there should be much more focus on the issue of automation.

10.5 E-navigation and ISO17894, are they known in the industry

The next couple of questions deal with the e-navigation proposal and the ISO17894 standard, that is described further previously in the thesis.

10.5.1 The e-navigation proposal of December 2005

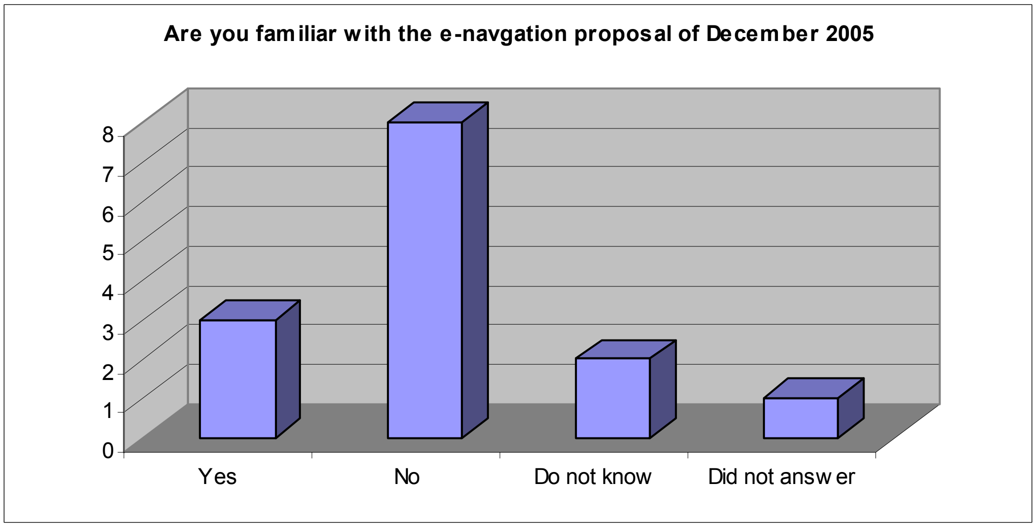

Figure 9-23 Familiarity with E-navigation.

The fact that so few were familiar with the e-navigation proposal of December 2005 was less surprising to me than the lack of knowledge about ATOMOS. The e-navigation proposal is as the title indicates only a proposal, and also relatively new at that.

None of the equipment suppliers were familiar with this proposal, five answered no to the question, two did not know, and one did not answer at all. It could be assumed that as these people are working as equipment suppliers they will learn more about e-navigation when it is no longer a proposal.

As neither of the respondents who works at shipbuilding yards have heard about the proposal either, the same might be true for them as a group.

Perhaps more surprising is the fact that only one of the respondents working at a classification authority has heard about the e-navigation proposal. However, working at a classification authority does not mean that you have to know about every proposal out there.

Both the respondent from an undisclosed workplace and the respondent from a research institute have heard about the e-navigation proposal. The respondent from a research institute also noted that the proposal is fairly "fluffy" at the moment, as it is not clear what practical implications it will get. He also says that this is an important issue, particularly with regards to electronic fairways and the like. However, it is not clear if e-navigation will include the BRM issue directly, or even indirectly. One of the respondents from a classification authority is positive towards the proposal.

10.5.2 The ISO17894 standard

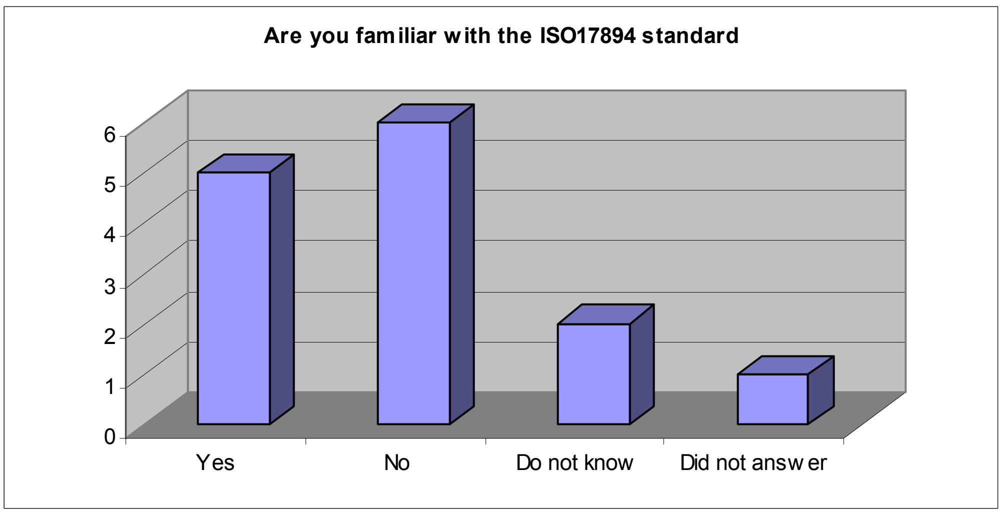

Figure 9-24 Familiarity with the ISO 17894 standard.

The ISO17894 standard is a standard which I have described in this thesis. I wanted to know if this standard is known to the people who work in the industry. It turned out that out of the 14 people that I had asked, five of them were familiar with the standard. Four of the equipment suppliers were familiar with the standard. This is a much higher turnout than what I got when I asked about the e-navigation, so I assume that this is a standard (e-navigation is not a standard) that is known, at least to some extent, throughout the industry. Another reason why this is perhaps surprising is that the standard is as mentioned previously in the analysis, almost identical to the ATOMOS proposition.

As with the e-navigation proposal, neither of the respondents from the shipbuilding yard had heard about the standard. This could mean that this part of the industry, shipbuilding yards, pay less attention to proposals and standards, however, it could also mean that the proposals and standards mentioned here are less relevant for them. Finally, as the shipbuilding yards are represented by only two respondents one should not generalize too much based on these answers. What is more surprising is that neither of the respondents working at classification authorities have knowledge of the standard. As with the respondents from shipbuilding yards, it is probably not a good idea to generalize. It is, however, a somewhat confusing result. One more person was familiar with this standard, and that is he from a research institute. The most surprising result gathered from this question is the fact that so many equipment suppliers were familiar with the standard, compared to people from other parts of the industry.

10.5.3 PES (Programmable Electronic System)

As explained in the chapter about this standard, it revolves around the principles for marine PES (Programmable Electronic System), and I wanted to know to which extent these principles are used in practice. It is worth noting that, when I made this question, anticipated a much higher rate of *yes* to the previous question. If the respondents are not familiar with the standard, it is not likely that they are familiar with the principles of the standard either.

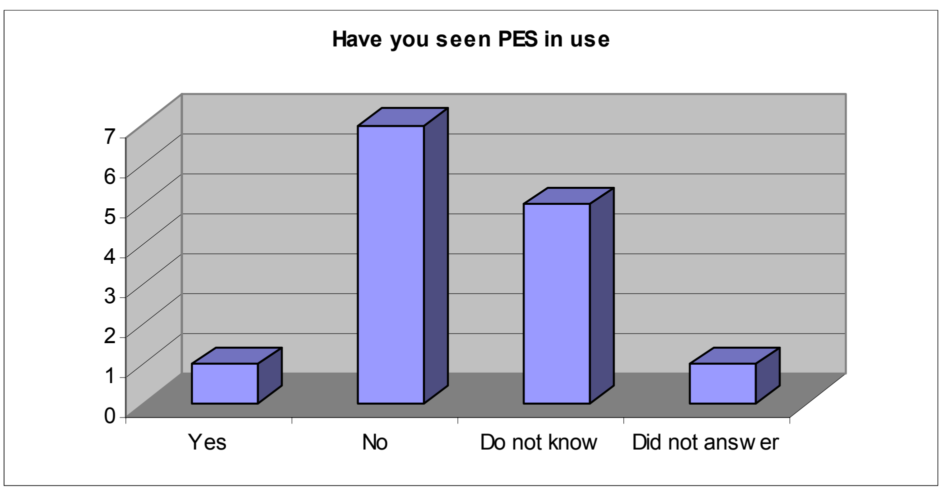

Figure 9-25 PES in use.

Not surprisingly, considering the previous question, only one of the respondents has seen PES in use. This person is an equipment supplier, he states that he has seen it in use in the cruise industry. The answer was pretty devastating for the ISO17894 standards, as these principles are the most important part of it. The fact that only one out of fourteen respondents from across the industry had heard about them is undeniably a bad result. The final question in the questionnaire gives the respondents the opportunity to elaborate on the issue of PES and its use in practice. The respondent from a research institute, who was familiar with the standard, but had not seen it in practice says the following: “This standard represents a new principle for technical standards in that it is much less prescriptive than previous standards. Lloyds Register claims that they make reference to this standard in their rules, but it is not clear to what degree they can enforce the standard”.

10.6 Conclusion of the initial questionnaire

The fact that the initial questionnaire had such a high rate of answers meant that I was able to learn a lot from it, as well as draw conclusions based on the answers.

The most positive result of this questionnaire is that the respondents, in general, are as concerned with safety as they are. It is however, surprising that, what should be known standards and regulations are as unfamiliar to most respondents as they are. I did not anticipate this. Although formal efforts to improve the safety in the industry might be little known, at least they are positive towards the issue of improved safety. If the respondents in general had been negative towards improved safety, this would have been a much bigger problem. As it is now, most of the respondents seem to be interested in learning more about the safety issues. Also, it is important to notice that the respondents seem to think that the level of safety is acceptable in their own organization, but not in the industry on general. This might pose as a problem, if they decide to learn about new efforts to improve safety. The participants might feel that this needs to be applied to the industry in general, but not to their own organization. This might, in turn, make the efforts pointless.

Another positive finding from the questionnaire is that most of the respondents, regardless of occupation, seem to have a lot of opinions regarding safety. Many of them had elaborate answers to my free text questions, which mean that I learned a lot from the answers. If all of these opinions somehow could be joined, to make up a standard or something similar to improve the safety, this would be very helpful. However, I do understand that as the marine industry is as large and differentiated in groups as it is, it is very hard to develop a group effort, and maybe even harder to actually enforce it in real life. Another important point is that the different parties of the industry are in competiton with each other to a certain extent. This makes cooperation harder. The fact that so few had heard about Atomos is a good example of this. The Atomos proposition was an effort to improve safety in the systems used on ships. Much effort was put behind it on order for it to be as good as possible, and the effort was even turned into a standard, the ISO 17894. However, this standard was fairly unfamiliar to most of the respondents as well. Nevertheless, I should probably be careful about being to negative towards the fact that there seem to be so little knowledge about specific efforts made to improve safety throughout the industry. It might be that there are some other standards and efforts that are widely known throughout the industry. However, no one mentions any such standards or efforts throughout the questionnaire, which means that I am doubtful of their existence.

Chapter 11 The follow-up questionnaire

This chapter concerns with the follow-up questionnaire. The follow-up questionnaire deals with the user interface and its level of safety more specifically. It also deals with how much knowledge the members of the industry have of official standards and propositions to improve the level of safety, like the initial questionnaire did. The follow-up questionnaire was made because the initial questionnaire did not provide as much insight into the thoughts about user interface as anticipated. The reason for this could be that the respondents focused on other propositions and standards than anticipated, which lead to less insightful answers from the respondents.

Before the analysis and discussion of the result, I have included a summary of the results.

11.1 Analysis and discussion of the follow-up questionnaire

11.1.1 Introduction

The results of the first questionnaire did not go as deeply into the user interface and safety issue as desired. The reason for this is probably that the knowledge about ATOMOS, ISO 17894 and e-navigation was much less than I anticipated. As a result of this, a follow-up questionnaire was made. This questionnaire has several questions concerning more specifically the user interface and safety. As user interface is an important part of my thesis I wanted to see if the recipients had any knowledge about this as well. The ISO 11064 standard concerns design of control centers, like the ones at the bridge of the ships. However, unlike with the first questionnaire I anticipated that this might not be very familiar to the recipients as it does not concern ships in specific. In my opinion, the industry has much to gain by getting to know the standard.

The questionnaire consists of 33 questions, where five are multiple choice type of questions, eight are yes or no type questions and 20 require free text answers. The recipients will need 10-30 minutes to complete the questionnaire, depending on their level of participation.

Unlike the first questionnaire, the follow-up questionnaire had a much lower rate of answers. In fact, only four of the recipients of the questionnaire chose to answer it. The group of recipients was the same as for the first questionnaire. This means that it is a lot more difficult to draw conclusions from the answers.

11.1.2 Background information about the participants

In the questionnaires' introduction part I asked the participants about their organizational role, as I did in the initial questionnaire. The recipients included one equipment supplier, two from a classification authority and the recipient from a research institute that was discussed in the opening chapter of this part of the thesis.

Unlike the last survey, this time all of the respondents are Norwegian.

11.1.3 What information did I get from the follow-up questionnaire?

In this part of the chapter I will go through the questions of the follow-up questionnaire and discuss the answers.

The questionnaire can be divided into nine subsections, these are:

1. Personal information
2. User interface in bridge systems
3. ISO 17894
4. Types of ships familiar to the respondents
5. The operators handling of bridge systems
6. Error and emergency handling
7. Alarms in the different systems
8. Training and development
9. ISO 11064 and other HCI relevant standards

Seeing that the degree of recipients answering this questionnaire was much lower than the degree of recipients answering the initial questionnaire, it is harder to draw conclusions this time.

11.1.4 User interface in bridge systems

Of the four recipients, three of them answered that the safety in the user interface for bridge systems is a prioritized issue. The last respondent chose to say that it was a three on a scale from one to ten, which implies that he does not prioritize it. The person who chose to answer the question was from a classification authority. This is interpreted as the person from a research institute, as well as the other from a classification authority and the equipment supplier feels that it is important. It is implied that, as three out of four find it important, the industry in general probably prioritize it as well. When asked for their opinion on the level of safety in the user interface for bridge systems the person that used the scale in the previous question chose to do so again, again with a scale from one to ten, he gave it three out of ten. Fortunately, the other person from a classification authority substantiated his/her answer. The answer indicated that the respondent felt that the user interface is often neglected and not prioritized. Design of equipment is left to manufacturers and hence integration of equipment to a work station can not be optimized. An improvement can be expected if one manufacturer is designing integrated bridge layout. This answer points to the fact that the classification authority is at least aware of the problem. The respondent from a research institute also answered the question, saying that IMO INS (Integrated Navigation System) and IBS (Integrated Bridge System) performance standards, which are forthcoming, addresses this issue directly. The level of safety in the user interface for bridge systems is very much a focus. However, the respondent from a research institute points to the same as the respondent from a classification authority and says that it is difficult to go further beyond state of the art systems. The reason for this is that these systems are put together with parts from different manufacturers. In addition to these issues, the respondent from a research institute says that existing rules, and particularly class interpretation of rules is in any case an obstacle to further developments. The equipment supplier however, did not answer at all.

The respondents were also asked if they are familiar with any efforts to improve the level of safety in the user interface. The equipment supplier chose not to answer this, while the respondent from the classification authority said yes, with no further comments. While this is a very short answer, at least it implies that he is familiar with efforts to improve the level of safety. The respondent from the classification authority mentioned the SOLAS V implementation of IACS. He also mentioned the effort that the respondent from a research institute mentioned in the previous answer, namely the revision of the IBS and INS standards. This is positive as it shows that these efforts are known to more than one group of the industry. The research institute respondent answered that IMO is very active. Also, several EU projects have worked with this issue. Examples of such projects are MarNIS, DISC I/II and ATOMOS, these are described in more detail in the ATOMOS and ISO 17894 chapter. The research institute respondents also said that national research projects are addressing this issue extensively.

The opinions of the respondents who chose to answer, point to the same results as in the initial questionnaire, it is difficult to enforce strategies across the industry. One part of the industry chooses to interpret it one way, while other parts focus on other issues. To ensure that the issue is taken seriously, the user interface and layout of the bridge should be designed from one manufacturer, not many independent parts. However, the designing manufacturer needs to have the safety in the user interface as a priority, otherwise it does not help much.

If the operator needs to monitor multiple screens at once, this might pose as a problem. The recipients were asked if they were familiar with any such problems at the bridge, two of them said no. The respondents who said no were equipment suppliers and from a classification authority. The second respondent from a classification authority said yes. The respondent from a research institute stated that there are issues in coordination, like when the operator is checking out alarms. Redundancy in hardware is also needed, in case one of the screens goes down. The respondent from a research institute continues by saying that there is also an issue of BMT (Bridge Resource Management), in how to utilize different screens by the bridge team. Finally, he says, in critical situations there are typically divisions of responsibility between the bridge team that will require multiple workstations (e.g. communication, navigation, safety/fire, machinery etc.). The issues with alarms are dealt with later in the questionnaire.

11.1.5 ISO 17894

As I believe that the ISO 17894 standard is an important tool in order to achieve an acceptable level of safety, I wanted to know how many of the respondents were familiar with it. The ISO 17894 standard is described in detail in chapter 7 of the thesis. As indicated in the initial questionnaire, the respondents were not very familiar with the standard. One said yes, one said no, one answered that he was partly familiar with it, and one said that he: *"Know about the standard, but is not very familiar with this"*. It was the equipment supplier who had the previous statement. Seeing that it is the equipment supplier who actually makes the equipment for the ship, it is very important that he has at least heard about the standard. However the most desirable would have been if he was actually familiar with the standard. The respondents from the classification authority did not have much knowledge of the standard. One answered no, while the other answered partly. This is also relatively surprising, as the classification authority probably would be the party enforcing the standard. The respondent from a research institute had heard about the standard, but chose not to elaborate.

11.1.6 The operators

I wanted to know if the operators at the bridge had to deal with several systems at once, this was a question which all of the respondents answered yes to. The respondent from a research institute elaborated by saying that it is true that they have to deal with several systems at once in most cases. The equipment supplier also elaborated, he said that the operator has to deal with several systems. He said that it is also common that an operator has working periods on different ships, meaning different systems and different working routines.

The point that the equipment supplier makes is an important one. It is important that the switching between systems and working routines is thought through, and that the operator does not get confused.

Another important issue is the level of difficulty for the operator in handling the systems. If it is too difficult, this might cause problems for obvious reasons, if the system is difficult to handle, it might be easy for the operator to make an error. When asking the respondents of the level of difficulty of the bridge systems, on a scale from one to five, two of the respondents answered that the level is *three*. Another respondent answered *two*, while the last respondent did not answer at all. This suggests that the level of difficulty is reasonable to simple, which is good.

11.1.7 Error and emergency handling

Perhaps more important, is the participants' assessment of how probable it is that the operator makes a mistake, on a scale from one to five. When I asked them about this, their answers varied. The equipment supplier answered *three,* which is reasonable, but the lower the probability is, the safer the system probably is. The respondent from a research institute had the lowest probability, as he answered *two* which is the most desirable of the answers. The respondents from a classification authority had the most disturbing answers, as one answered *four*, while the other answered *five*. If this is true it means that the operator is almost certain to make a mistake, which is very undesirable. However, it might be the case that the respondent had both minor and major mistakes in mind when answering. This would mean that their answers are not as catastrophic. The most desirable should however be to have the probability of the operator making a mistake as low as possible.

When the mistake has been made it is important that it is detected, either by the system or the operator. When asking the respondents about this they had different answers. The respondent from a research institute answered that this is dependent on the error. One of the respondents from a classification had a somewhat similar answer, as he said that there are huge differences between systems concerning the built-in-detection facilities. The other respondent from a classification authority answered that the error is likely to be detected if the system is complied with the Integrated Bridge System performance standard. The respondent who is an equipment supplier elaborated more than the others. His/her answer was: “I'm not familiar with how the other suppliers’ equipment works. We deliver the integrated alarm system. Operational errors are difficult to do in our system, but parameter setting errors and calibration errors are possible to do and will not be detected.” This is a promising answer, as it limits the operators’ possibilities of making a big error.

It is as important to detect the error in the system as actually being able to rectify it. The next question was concerning this. However, the answers were somewhat inconclusive, as the person who stated that there were huge differences between systems in the last question, simply stated that his/her answer was the same for this question. This respondent was from a classification authority. The other respondent from a classification authority answered yes. However, I would have liked to know more about the background for the answer. The respondent from a research institute answered with a question: “What kind of error?” And elaborated by saying: “If he orders full astern at the wrong moment there are physical constraints to what can be undone.
The INS standard will explicitly suggest a kind of undo function in navigational equipment for correcting mistakes”. And finally, the equipment supplier answered maybe. Once, again, seeing that there are only four respondents to this questionnaire, it is difficult to say something one way ore the other of what these answers indicate.

11.1.8 Training and development

As explained in the chapter about psychology there are several factors to take into consideration when humans operate the system, I wanted to know if any of these factors were taken into consideration when making the system, and training the operators.

When asked if the operators are trained to handle stressful situations, the answers were divided, as two of the respondents said *yes* and two said *no*. This was disappointing as this was something that I would have liked to know more about. The same results appeared when I asked whether or not the operators are trained in emergency handling. Two of the respondents answered *yes*, while two said *no*. Sadly, the same results appeared again when asked whether or not the operators go through periodical drills in emergency handling. Fortunately, this section of questions also included a free text question, which resulted in more information than the previous questions. The respondents were asked how much training is required to operate the system. The first respondent from a classification authority answered that it is important to design a system so that the emergency/backup operation is as similar to the normal operation as possible. Then the transfer to the back-up systems will be less prone to mis-operation and error and limit training requirements. The other respondent from a classification authority pointed to the fact that the training differs a lot from system to system, and operator to operator. The equipment supplier continues to talk about the system that his firm makes, and says that the operator needs a couple of hours to go through the system. The fact that the equipments supplier refers to the system that they make, is good, as this means that he actually knows what he is talking about. The last respondent, from a research institute does not know. The respondents also answered whether or not frequent refreshment courses is needed, and three said *yes*, while one said *no*.

The respondents are in agreement that the training ensures that the operator understands the task at hand, as three of them say *yes* to the question. Another important issue that I have described in the psychology chapter is that at least some of the operators should be a part of the development of the system. When asked about this, two of the respondents say that they are, one says *no* and one does not answer. The respondent from a research institute and one of the respondents from a classification authority says *yes*. In the ISO 11064 chapter and in the psychology chapter it is mentioned that it is important that the operator tasks do not get repetitive and routine. When the respondents are asked to characterize the operator tasks, three of them describe it as *repetitive and routine*. This is disappointing, as it is the opposite of what is recommended. The respondent from a

classification authority, the respondent from a research institute and the equipment supplier give these answers. The last respondent answers *other*. When asked to elaborate he says that the execution of tasks depends of the phase of the transport. They may be very repetitive during certain phases of the transport, and the opposite in other phases. The respondent from a research institute elaborated by saying the following: "The problem is that most of the time the ship sails straight forward and not much happens. Alarms that indicate a change in condition may be overlooked in this mode due to habit.
In critical situations, the operator may need additional information from the system than during normal operation. One example is that a status display may be more appropriate in an emergency situation than a more event based alarm list, while the opposite is true in "normal operation".

I believe that it is impossible to avoid that the tasks are repetitive and routine in some phases, however, this should be avoided from happening too frequently.

It is difficult to draw any conclusions based on the answers in this section, since they differ so much. Also, it is not clear whether or not the respondents are answering based on the same conditions or understanding of the question.

11.1.9 Alarms in the different systems

Firstly, I wanted to know if the respondents felt that there are too many, too few or enough emergency alarms in the systems. In the chapter about "Accidents due to poorly designed interfaces", chapter 6, I described how the operators where overwhelmed by the amount of alarms, and had difficulties separating the important ones from the less important ones. What I wanted to know is whether or not this is an issue in marine systems.

To start with, the answers given by the two respondents from a classification authority differed greatly. One said that there are enough alarms, while the other stated that there are far too many. The answers from the respondent from a research institute and the equipment supplier offered a bit more insight. The respondent from a research institute said that the main problem is that it is difficult to assess the criticality of alarms particularly when there are too many of them. Furthermore, he said the following: "Alarm patterns will be very different in different situations: Normal op: Irrelevant alarms take attention away. Emergency: many alarms make it difficult to assess situation. Emergency: irrelevant alarms may distract". This is exactly what I thought and have described as a potential problem. The equipment supplier describes the same problem, when he says that there are far too many alarms. And it is important that the "real" emergency alarms do not "disappear" in the alarm jungle. As three of the respondents agree that there are too many alarms, it indicates that this might pose as a problem in the maritime industry as well. As a majority of the respondents are aware of the problem, we can hope that the issue will be dealt with.

A more surprising result was presented when the respondents were asked whether or not the most critical alarms are easy distinguishable from the less important alarms. Two of the respondents answered *yes*, while the other two answered *no*. Unfortunately, it is hard to draw any conclusions based on that.

11.1.10 ISO 11064 and other relevant HCI standards

The ISO 11064 standard has been described in detail in the thesis [19] and I feel that it is an important tool that designers of systems and control centers can use. Unfortunately, none of the respondents are familiar with the standard. For more information see "The short summary of the follow-up questionnaire". However, the respondent from a research institute says that these standards are required which is very positive.

11.2 Conclusion of the follow-up questionnaire

The follow up questionnaire was an effort on my part to gain more insight into the handling of safety in the user interface in the industry. I got some information from the initial questionnaire, but I wanted to know more, specifically about the issues of training, multiple screen problems and the familiarity of ISO 11064.

As with the initial questionnaire, I was very pleased by the effort made by the respondent to answer the questionnaire. Some had elaborate answers to all of the free text questions. However, as there are only four respondents to this questionnaire, I am unable to draw conclusions based on their answers, to the same extent as in the initial questionnaire. This is especially true as the respondents did not agree on many of their answers. It is however my opinion that the results here, seem to be similar to the results from the initial questionnaire. The respondents have a lot of opinions, and seem to be very concerned about the issue. But little specific knowledge throughout the industry is shown. As with the initial questionnaire I feel that it would be a good idea to gather the opinions and see if anything can be made that would be valid for the industry in general.

PART V: CONCLUSION AND FUTURE WORK

Chapter 12 Overall conclusion:

This chapter contains the overall conclusion of the thesis.

In this thesis I have presented relevant standards, propositions and other efforts made to improve the safety within the maritime industry and the safety within the user interface in computer systems of such systems. I have also shed light on the fact that the members of the industry seem to be interested in making an effort to improve the safety. However, I have also brought to light a more surprising fact, namely that the standards, propositions and efforts described in the thesis, that would be helpful to the industry in general, are little known. This is true for both efforts made to improve safety in computer systems in general and also, efforts made to improve safety aspects in the user interface on the bridge control centers. If these two facts somehow could be combined, the industry would have come a long way.

From my work with the surveys, I learned that the members of the industry are full of opinions about the level of safety, and also that they are, in general, not pleased with the level of safety as it is today. This should provide excellent grounds for improvement. However, the problem might be that the industry is just too heterogeneous and differentiated, and this means that it will be difficult to reach a consensus which everyone can agree upon. As mentioned in the conclusions of the initial questionnaire, it is also important to remember that the different parties in the industry are in competition with each other. The competition factor might be what happened to efforts like the Atomos proposition or the ISO 11064 standard. The different groups that make up the industry felt that it did not apply to them, and therefore did not find it useful to read up on it. Another issue that might have failed the ISO 11064 standard is that it is not specific for the marine industry, it was made for designers of control centers in general and not industry specific. This might have lead to it not being known in all the industries that could have used it.

12.1 Main results from the surveys

The main result that I have reached from the work with my thesis is that there is a lot of potential for improving the level of safety in the maritime industry. Thankfully, the results of the answers from the surveys indicate that the members of the industry are more than prepared and willing to work on it. The problem is that it is difficult to get the whole industry to gather behind a joint effort. The reason for this is that the industry is heterogeneous and in competition with each other. Another important result from the work with the thesis is that the members of the industry are to a large degree not familiar with official efforts made to improve the level of safety.

Chapter 13 Future work

As described in the conclusions of the thesis as well as both the questionnaires. I believe that much could be gained if the members of the industry gathered, regardless of group and tried to make something together. There are a lot of opinions and knowledge in the industry that seems to be unused. If the participants of such an effort could reach a conclusion in some form that all the different parties could relate to, it could potentially provide a great tool in an effort to improve safety, both in general and in the user interface in specific. But as previously mentioned it is hard to develop something that everyone agrees to and can work with. These are the most important issues that should be dealt with. The members of the industry should ask themselves how they can participate in making the industry more safe, and a real effort should be made to make a standard or proposition that everyone can stand for. The main issue standing in the way of this happening seems to be the fact that several of the participants in the industry are in direct competition with each other. When trying to deal with such issues, one needs to allow for such considerations.

PART VI: APPENDICES

List of abbreviations

AIS	*Automatic Identification System*
BRM	*Bridge Resource Management*
COTS	*Commericial-off-the-shelf*
ECDIS	*Electronic Chart Display and Information Systems*
GMDSS	*Global Maritime Distress Safety System*
HCI	*Human Computer Interaction*
IACS	*International Association of Classification Societies Ltd.*
IALA	*International Association of Marine Aids to Navigation and Lighthouse Authorities*
IBS	*Integrated Bridge System*
IHO	*The International Hydrographic Organization*
IMO	*International Maritime Organization*
INS	*Integrated Navigation System*
ISM	*The International Safety Management Code*
ISO	*International Standardization Organization*
MarNIS	*Maritime Navigation and Information Services*
NORSOK	*Standards to be used on Norwegian socket*
OOW	*Officer Of the Watch*
PES	*Programmable Electronic System*
SCC	*Ship Control Centre*
SD	*Sjøfartsdirektoratet*
SMICT	*Safe Maritime ICT*
SIL	*Safety Integrity Level*
SURSHIp	*Survivability for ships*
TMI	*Three Mile Island*

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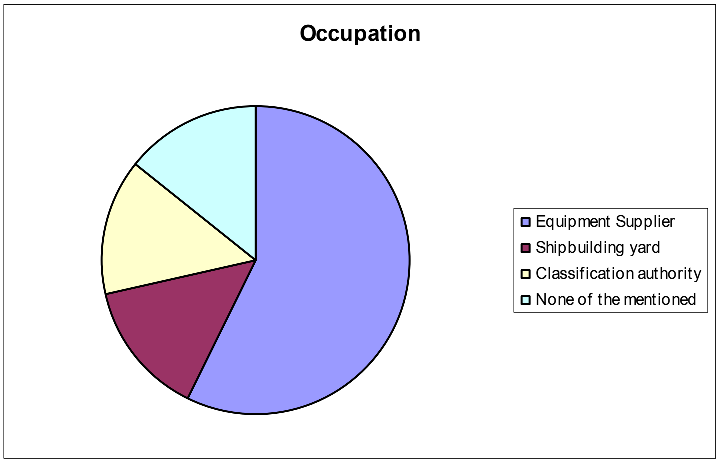
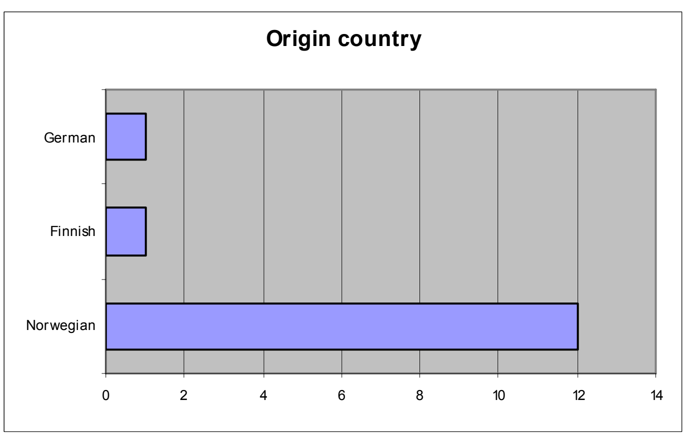
A short summary of the results of the questionnaire:

1. **<u>Which part of the industry do you belong to?</u>**



Eight of the people who answered the questionnaire works in the equipment supplier part of the industry. Two works at a shipbuilding yard, two works at the classification authority and two says none of the above. However we know that one of them is a research director at SINTEF.

2. **<u>In which country do you reside?</u>**



Twelve are Norwegian, one is Finnish, one is German.

3. **<u>How do you think the safety issue is handled in your company/organization today?</u>**

Seven find that the level and treatment of the safety issue in their organization is good, four find it satisfying, one does not have an opinion and two think that it is very good.

4. **<u>Could you please elaborate your opinion given in the previous question of how you think safety is handled in your company/organization today?</u>**

<u>Person 1:</u> Safety in our system is building on solid hardware and user protected input to software. Using XP Embedded and write filter, all user data is copied to RAM during startup.

All user changes and also effects of sudden shutdown to OS is then only effecting the data stored in RAM.

<u>Person 2:</u> 1. Safety has a high priority; it's taken seriously. 2. Still a potential to improve procedures and work practices concerning safety issues.

<u>Person 3:</u> Understanding and implementation of rules from Class and authorities.

Close cooperation with the class authorities. Use of cerified safetey equipment. Use of QA rutines.

<u>Person 4:</u> Safety issues are always classified as priority one class.

<u>Person 5:</u> -

<u>Person 6:</u> Through our QA system and internal testing, I think that we are taking into account all failure modes.

<u>Person 7:</u> My company are using a lot of resources to keep us up to date regarding new regulations etc. and throughout all the years we have been in the business we have proven that our products are handling safety in a good way.

<u>Person 8:</u> -

<u>Person 9:</u> -

<u>Person 10:</u> Some people are looking to their own systems, but it is necessary to have a look over all systems, which can influence each other.

<u>Person 11:</u> We have close dialogue to class, customer and yard.

<u>Person 12:</u> Safety is handled by implementing class rules, IMO requirements, IEC performance standards and work in developing and implement new standards, rules and regulations.

<u>Person 13:</u> Not applicable

<u>Person 14:</u> To the extent needed to satisfy IMO requirements

5. **<u>How do you think the safety issue is handled in your shipping industry in general today?</u>**

Four out of thirteen find that the general level and treatment of the safety issue in the industry in general is good, while two out of thirteen doesn't have an opinion, three think it's satisfying, and the last five think that the level is poor.

6. **Could you please elaborate your opinion given in the previous question of how you think safety is handled in the shipping industry in general today?**

Person 1: There are big variations regarding on location.

Person 2: Don't have enough marine industry experience to have an opinion.

Person 3: Class authorities have probelmes with the total overview of systems interconnected. Equipment suppliers can "hide" (deliberat or not) safety critical functions. This will only come to the surface when a certain situation occur.

Person 4: Some shipyards are very good, some are not so good when it comes to the safety issues during building the ship.

Person 5: There is a major problem with lack of competance regarding interface between de different systems.

Person 6: My answer is given for the general feeling of the Norwegian industry.

Person 7: I think that most of the shipping company are showing with there behavior that they are handling safety in a good way.

Person 8: -

Person 9: -

Person 10: Also here, the owner and the different system suppliers have to see the complete ship.

Person 11: Some yards are very good, because they understand the importance in good dialogue with all the sub suppliers. The interface beetween the different systems are, in my opinion, very important regarding the safety. But the most yards don't involve in the interface between the systems, and therefore it's up to the subsuppliers to decide.

Person 12: Safety is mainly dependant on getting properly trained and qualified personnel who can ensure that the maintenance and operation of the ship is adequate. Safety is also dependant on ship-owners having sufficient focus and budget to implement the ISM system and get qualified personnel.

Person 13: Accidents are going down and safety is an important issue in most of the industry. There are, however, issues that could be handled better, e.g.:

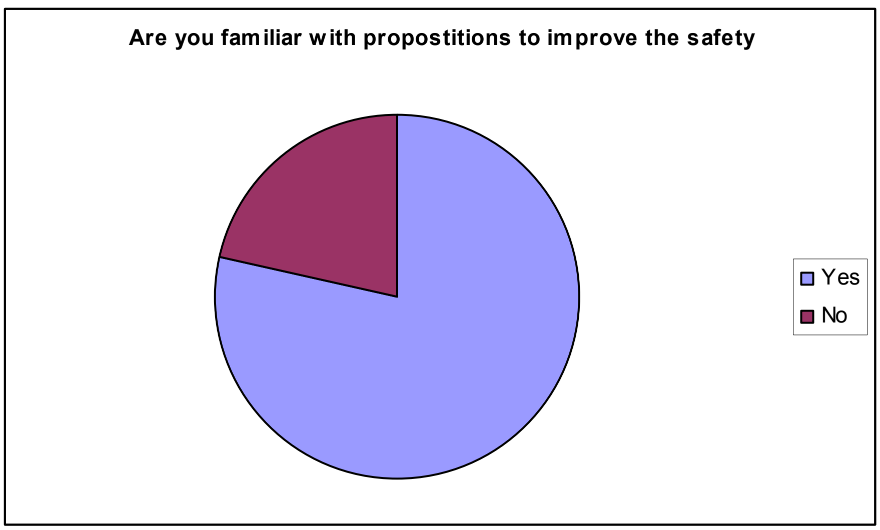
- Stressing work conditions in tense situations (manning, work hourse, shifts)

- Still problems with consistency in bridge systems, e.g., on alarm handling, look and feel etc.

Person 14: Money is often the guidance for how much work is to be invested.

7. Are you familiar with any propositions to improve safety in the shipping industry?

Eleven out of the fourteen are familiar with propositions to improve the safety in the shipping industry.



8. Would you like to explain your answer further? What propositions are you familiar with?

Person 1: DNV SMICT project.

Person 2: Involved in DNV project to look at class rules for on-board control software.

Person 3: *Projects conducted by class authorities that focus on safety items. These projects cooperate with the industri and will end up in new and better rules. I.e DNV COTS project and DNV SMICT project.*

Person 4: *On some shipyards, there are special safety at work documents to be read by all workers.*

Person 5: -

Person 6: *SMICT project.*

Person 7: -

Person 8: *IMO propositions/ National administration propositions.*

Person 9: -

Person 10: *There are some work shops from the classes and the IEC groups.*

Person 11: -

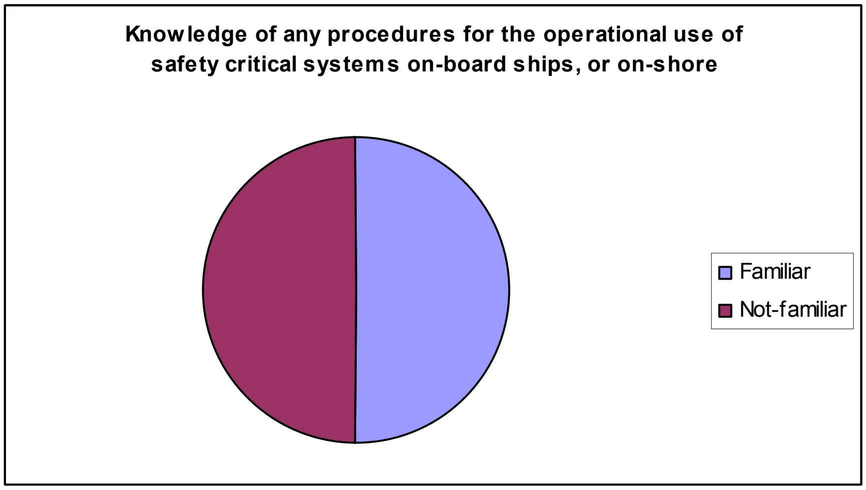
Person 12: -

Person 13: *IMO is continuously working on this with help from standards organisation, e.g., IEC and ISO. Several EU projects are working in this area, e.g., Flagship, Safedor, Intership etc. Also regional initiatives, Safety@Sea, SURSHIp and others work in the area.*

Person 14: *All basic requirements needed for an equipment manufacturer.*

9. Do you have knowledge of any procedures for the operational use of safety critical systems on-board ships, or on-shore?

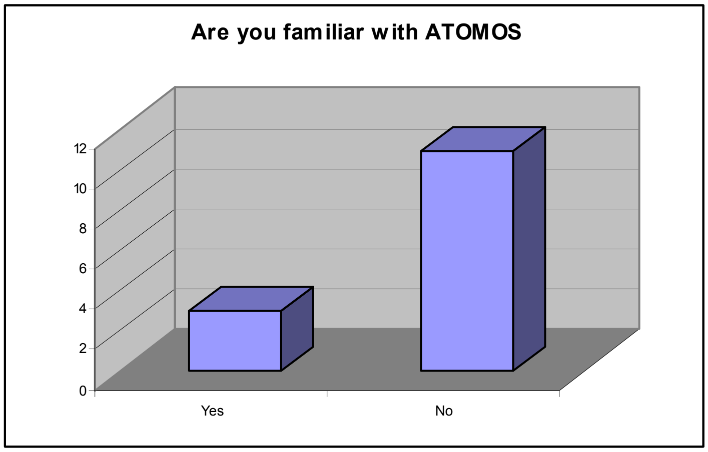
Seven have no knowledge of procedures for operational use of safety critical systems on-board or on-shore. Seven of the respondents have knowledge of procedures.



10. <u>If you answered yes, which procedures for operational use of safety cfritical systems on-board or on-shore do you have knowledge of?</u>

One of the four has knowledge of the IEC61508 (SIL) and NORSOK procedures. One answered yes to the previous question but doesn't mention what procedures he/she is referring to. One is familiar with everything related to ISM. The last is familiar with bridge procedures. One answered this: ISM and ISO certification requires that operations and procedures are documented, implemented and maintained. The last one who told us about the procedures he or she is familiar with answered: Most critical ship systems have procedures, at least in the form of IMO performance standards. Other requirements may be for documentation, through e.g. INS and IBS standards. Also, the ISM code will require procedures for most critical operations. Another one answered the following: Rules and regulations for closed loop regulation systems.

11. <u>Are you familiar with the Atomos IV, Revision, WP8.5 Rationale for Solas Regulation V/15 Template[1]?</u>



Only three out of the fourteen are familiar with ATOMOS IV.

12. <u>If yes, do you know of any of the parts of the Atomos IV regulation used in practice?</u>

As a result of this five doesn't know whether or not they've seen the ATOMOS IV regulation in practice, and the remaining nine knows that they haven't seen it in practice.

13. <u>If you are familiar with the Atomos IV proposition, do you think the proposals in the regulation are sufficient?</u>

No one has an opinion on the propositions that ATOMOS IV makes.

14. <u>Where have you seen the Atomos IV regulation used?</u>

Also no one has seen the ATOMOS IV regulation in use, except from one who's seen it in use by the classification authority.

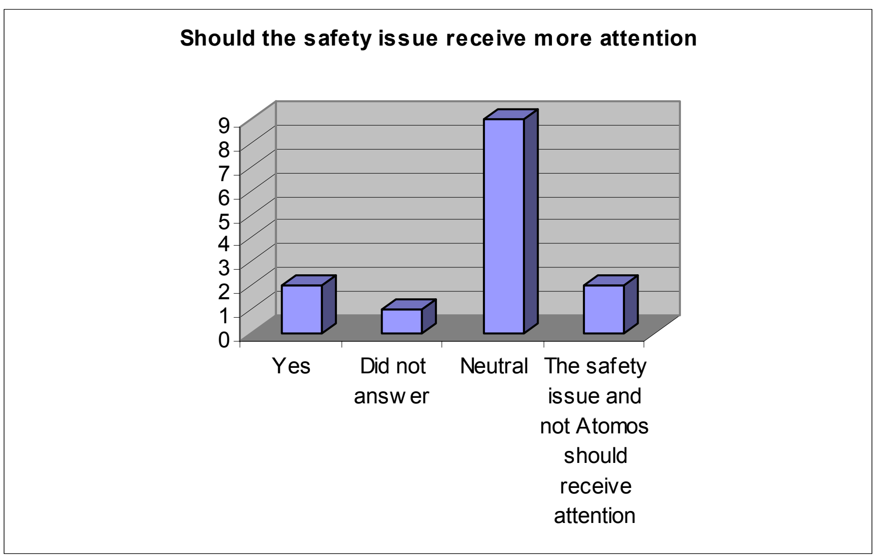
15. <u>What is your general opinion on the Atomos IV regulation?</u>

One is negative while the rest have no opinion on the issue.

16. **<u>Could you please elaborate your opinion given in the previous question of your general opinion on the Atomos IV regulation?</u>**

Only one of the respondents chose to answer this question, he or she answered the following: The ATOMOS series of projects did produce quite a few reports during their lifetime. AtomOS IV, according to rumors, also implemented some of the developed principles in a Swedish Icebreaker. This was not very successful and the special equipment was (rumored) to be removed after a while. Some results from ATOMOS have been adopted by Lloyd's register, i.e., on design principles for programmable electronic (PE) equipment. This has also been converted into an ISO standard. However, this is not related to the document at hand.

17. **<u>In your opinion, should the regulation and the safety issue receive more attention?</u>**

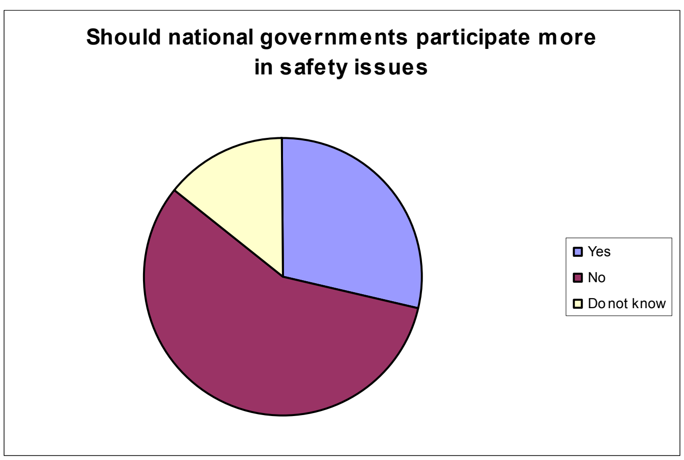


Two answered not familiar to this question, six were neutral, two answered yes, and the two last ones thinks that the safety issue, and not ATOMOS IV should receive more attention, one didn't answer at all.

18. Could you please elaborate your opinion given in the previous question of whether or not the safety issue and the regulation should receive more attention?

There were three answers to this question. One answered: Safety is an important issue. We are at a good level in safety thinking now. The other answer said: It is more important for both suppliers and vendors to have a safety issue than have a regulation focus. This answer was given by the same person that said that the safety issue and not ATOMOS IV should receive more focus. And the third answer was: IMO NAV has formed a correspondence group that among other things will look at the BRM (Bridge Resource Mangaement) issues in conjunction with SOLAS V/15. People from ATOMOS is participating there and will bring their experience into the work. The draft standards will most likely be delivered to NAV 43 in July.

19. Do you think the national governments should take a larger part in the development of safety regulations in general for the industry?



Eight answered no to this question, two didn't know and four answered yes.

20. Could you please elaborate your opinion given in the previous question of whether or not the national governments should take a larger part in the development of safety regulations?

Person 1: *This to guarantee same rules for all.*

Person 2: *Can see both pros and cons, so I don't really have an opinion.*

Person 3: *This is an international task.*

Person 4: -

Person 5: -

Person 6: *I do think that we as of today have a healthy interaction with the government and they should keep up the involvement at present level.*

Person 7: -

Person 8: -

Person 9: *IMO*

Person 10: -

Person 11: -

Person 12: *Safety regulations need to be developed on an IMO level to avoid too many special requirements for different flags which will not benefit the industry.*

Person 13: *Sjøfartsdirektoratet is participating actively together with other parties, i.e., DNV and MARINTEK. However, it looks as if SD does not have enough resources to really follow up on this as much as one could wish for.*

Person 14: *At least as much as today.*

21. How do you think the industry should address the safety issue?

Person 1: *Verification and validation*

Person 2: *Development and management, analysis of requirements, verification and validation, evaluation, dissemination.*

Person 3: *Development and management, verification and validation.*

Person 4: *Development and management, verification and validation, evaluation.*

Person 5: *Analysis of requirements, verification and validation.*

Person 6: *Development and management, verification and validation, evaluation.*

Person 7: *Analysis of requirements.*

Person 8: *Development and management.*

Person 9: *Other.*

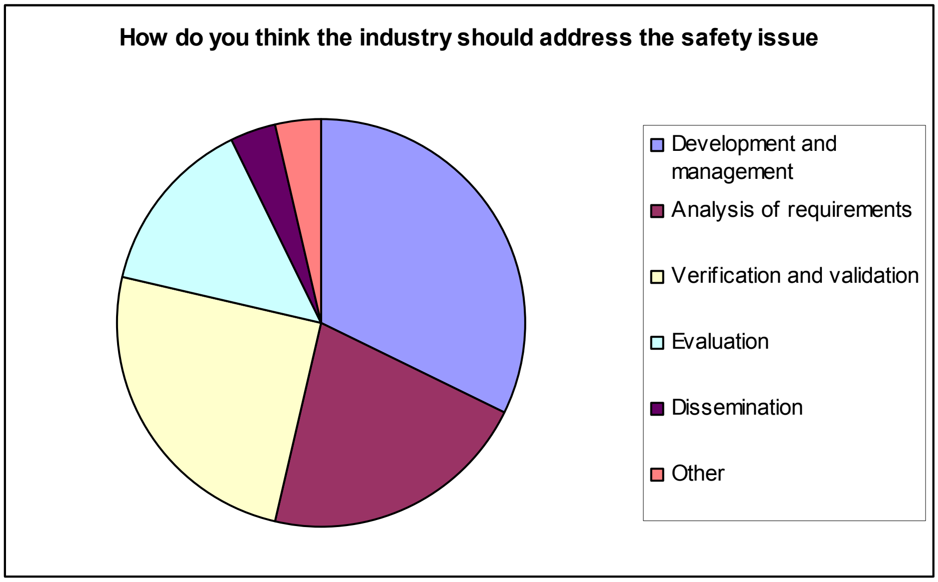
Person 10: *Verification and validation.*

Person 11: *Development and management.*

Person 12: *Development and management, analysis of requirements, evaluation.*

Person 13: *Development and management, analysis of requirements.*

Person 14: *Development and management, analysis of requirements.*



22. <u>Could you please elaborate your opinion given in the previous question of how you think the safety issue should be addressed?</u>

<u>Person 1:</u> -

<u>Person 2:</u> There are no approaches to improving safety issues that can be ignored by the industry.

<u>Person 3:</u> -

<u>Person 4:</u>-

<u>Person 5</u>: -

<u>Person 6:</u>-

<u>Person 7:</u> It is important that the industry develop sufficient safety solution and the solutions should be based on requirements.

<u>Person 8:</u> -

<u>Person 9:</u> Implementation of existing standards and regulations.

<u>Person 10:</u> The industry has to look to the regulations and to say, what it technical possible with the new technologies. Sometimes the words have to be changed. Then it is possible to get the same degree of safety, but the costs of the system will be much less.

Person 11: *It is very important that the industry has competent persons to follow up the system and sub suppliers.*

Person 12: *Safety issues needs evolution and updates to follow the industry development of new technology. The industry is challenging technical borders, systems are becoming more integrated and complicated and maintenance, possibilities for emergency operation and education of personnel is not following the development.*

Person 13: *These issues should be addressed through IMO instruments and corresponding technical standards (from ISO and IEC in this case). Industry would then normally comply with these standards. IACS will also put in place requirements together with the individual class societies.*

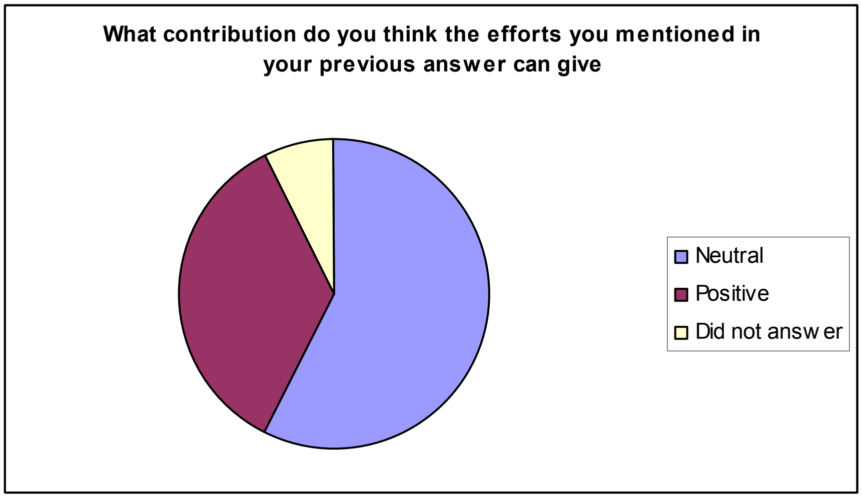
Person 14: *Develop according to requirements.*

23. Are there any propositions or efforts in particular that you would like to point out?

One answered the IMO e-navigation to this issue, one told us to see the previous answer and another answered that there are just too many.

24. What contribution do you think the efforts you mentioned in your previous answer can give?

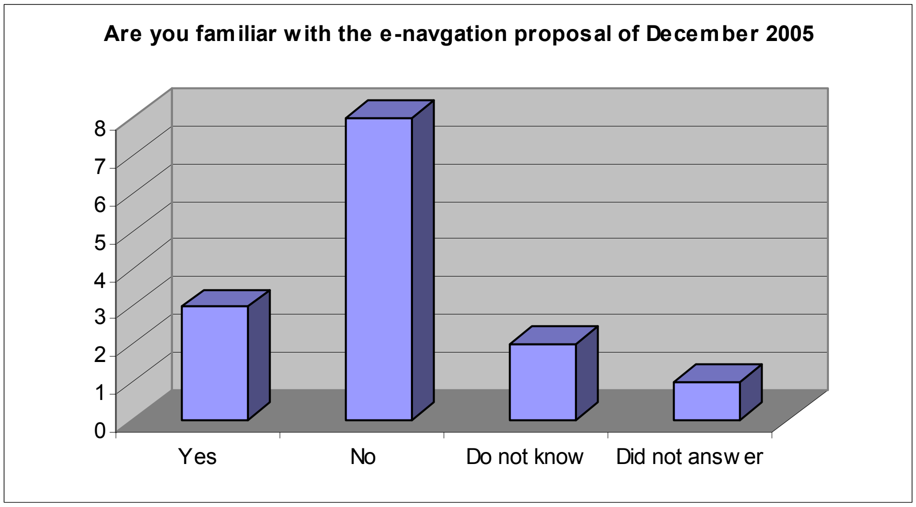
Eight were neutral to this question. The last five were positive, one didn't answer the question.



25. <u>**If you have any other suggestions or thoughts regarding the subject of safety in shipping, please include them here.**</u>

Three of the recipients answered this question, he/she wanted much more focus on automation. The other answered: Safe ship needs to be simple and intuitive to operate and maintain. ISM code is implemented and this has already improved operation of ships and ship management. And finally the third answered: More involvement from industry in rule-making would be good.

26. **Are you familiar with the e-navigation proposal of 19th of December 2005[2]?**

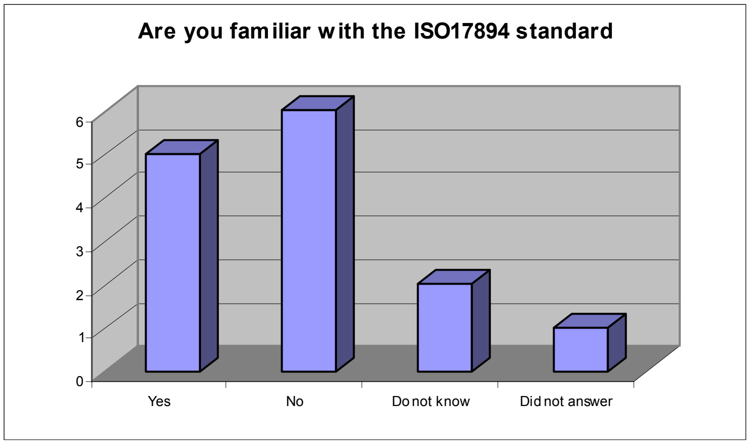


Eight answered no to this question, while two didn't know, three answered yes, and one didn't answer the question at all.

27. <u>If yes, do you have any thoughts or feelings towards the e-navigation proposal?</u>

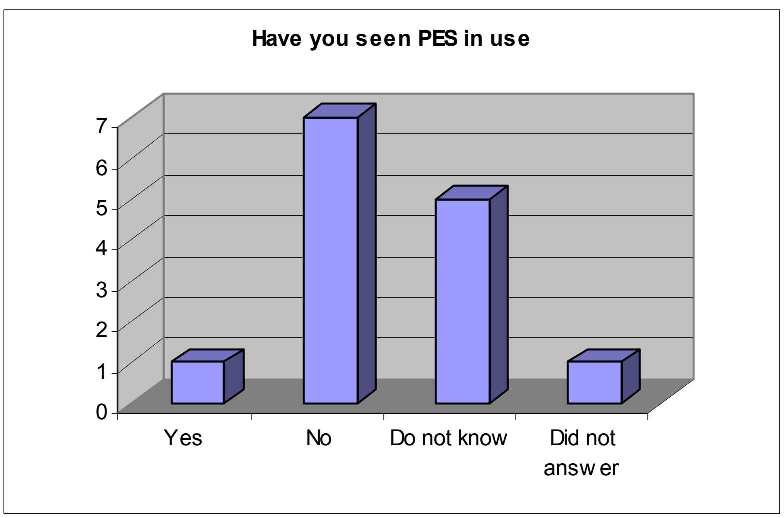
One is positive towards the proposal. And one answered: It is fairly "fluffy" at the moment. It is not clear what practical implications it will get. The issue is important, particularly with regards to electronic fairways and the like. However, it is not clear if e-Navigation will include the BRM issue directly or even indirectly.

28. <u>Are you familiar with the ISO 17894 Standard[3], "Ships and marine technology- Computer applications- General principles for the development and use of programmable electronic systems in marine applications?</u>



Five were familiar with the standard, six said no, two did not know and one didn't answer.

29. **<u>Have you seen the principles for marine PES (Programmable Electronic System), from this standard, used in practice?</u>**



Five didn't know, one answered yes, one didn't answer at all and seven answered no.

30. **<u>Could you please elaborate your opinion given in the previous question of whether or not you have seen the principles for marine PES (Programmable Electronic System), used in practice?</u>**

The one who answered yes to the previous question answered that he or she had seen in use in the cruise industry. One of the respondents who answered no said the last question said this: These standards represents a new principle for technical standards in that it is much less prescriptive than previous standards. Lloyds Register claims that they make reference to this standard in their rules, but it is not clear to what degree they can enforce the standard.

31. <u>Thank you for taking the time to answer this questionnaire. If you wish to get an update on the results, please include your e-mail address here, this will not affect your anonymity</u>:

Four left their e-mail address.

32. <u>Would you be willing to participate in a follow-up interview?</u>

Six answered yes, unfortunately I received only three e-mail addresses.

A short summary of the results of the follow-up questionnaire:

1. Which part of the industry do you belong to?

Two of the respondents are from classification authority, one is from Marinetek and one is an equipments supplier.

2. In which country do you reside?

All of the respondents are Norwegian.

3. Is the safety in the user interface for bridge systems a prioritized issue?

Three of the respondents answered yes to this question, while the last respondents answered that it is a three on a scale from one to ten.

4. Do you have an opinion of the level of safety in the user interface for bridge systems?

Person 1: The level of user interface is often neglected and not prioritized. Design of equipment is left to manufacturers and hence integration of equipment to a work station can not optimized.
An improvement can be expected if one manufacturer is designing integrated bridge layout.
Person 2: IMO INS (Integrated Navigation System) and IBS (Integrated Bridge System) performance standards (forthcoming) addresses this issue directly. It is very much a focus, but it is difficult to go further beyond state of art as systems are put together with components from different manufacturers. Also, existing rules and particularly class interpretation of rules is in any cases an obstackle to further developments.
Person 3: On a scale from 1-10: 3
Person 4: -

5. Are you familiar with any efforts to improve safety in the user interface for the bridge systems?

Person 1: SOLAS V implementering av IACS gjennom fellestolkning.
Revisjon av Integrated Bridge System standard og INS standarden.
Person 2: IMO is very active. Several EU projects have worked on thiss issue (MarNIS, Flagship, ATOMOS, DISCI/II etc.). National research projects is also addressing this extensively.
Person 3: Yes
Person 4:-

6. Do you have knowledge of any issues posed by the use of multiple screens at the bridge?

Person 1: No
Person 2: There are coordination issues on, e.g., checking out alarms.
You need redundancy in hardware, in case on screen goes down.
It is also an issue of Bridge Resource management (BMT), how to utilize different screens by the bridge team.
Finally, in critical situations, there are typically a division of responsibility between the bridge team that will require multipleworkstations (e.g., communication, navigation, safety/fire, machinery etc.).
Person 3: Yes
Person 4: No

7. Are you familiar with ISO17894, ?Ships and marine technology- Computer applications- General principles for the development and use of programmable electronic systems in marine applications?

To this question one of the respondents answered no, one answered yes, a third answered partly while the last respondent said the following: "Know about the standard, but a not very familiar with this."

8. What types of ships and their systems are you familiar with?

Person 1:
- *Bulk carrier*
- *Cargo ship*
- *Ferry*
- *Passenger ship*
- *Supply ship*
- *Tanker*

Person 2:
- *Bulk carrier*
- *Cargo ship*
- *Cruise ship*
- *Ferry*
- *Passenger ship*
- *Tanker*

Person 3:
- *Bulk carrier*
- *Cargo ship*
- *Supply ship*
- *Tanker*

Person 4:
- *Cargo ship*

- *Ferry*
- *Supply ship*
- *Fishing vessel*
- *Tanker*

9. What types of ships and their systems are you familiar with?

Person 1: -
Person 2: -
Person 3: IBS, INS, TCS, ecdis, arpa, radar, autopilot, gyro, gps, SDME, ES, steering control.
Person 4: -

10. In reference to the ships you were familiar with from the previous questions. Does the operator working at these ships have to deal with several systems at once?

Person 1: Yes
Person 2: Yes in most cases. A simple example is communication (GMDSS) and navigation. One un-manned engine rooms, the OOW also has to handle engine/automation alarms.
Person 3: Yes
Person 4: Yes, the operator has to deal with several systems. It's also common that an operator has working periods on different ships, meaning different systems and working routines.

11. Could you describe what kinds of bridge systems the operators have to deal with?

Person 1: Steering/ propulsion systems, navigation systems, communication systems, alarm systems.
Person 2: See previous answer.
Person 3: Arpa, edcis, steering control systems, alarm systems, sensor indicators, communication systems, cargo/ballast control system.
Person 4: The operator has to deal with the integrated alarm system, the digital map system, radar system, navigation system, loading computer .....

12. How difficult on the bridge systems that you mentioned in the previous question to handle for the operator? On a scale from 1-5.

Two of the respondents answered 3 to this question, another answered 2, the last respondent did not answer this question at all.

13. When using the bridge systems, what is the probability of the operator making a mistake? On a scale from 1-5.

One of the respondents answered 2 to this question, one answered 3, one answered 4 and the last respondent answered 5.

14. When the operator has made an error, will the system detect this?

Person 1: Most likely only if the system(s) are complying with the Integrated Bridge System performance standard.
Person 2: Dependent on error.
Person 3: There are huge differences between systems concerning built-in-detection facilities.
Person 4: I'm not familiar with how the other suppliers equipment work. We deliver the integrated alarm system. Operational errors are difficult to do in our system, but parameter setting errors and calibration errors are possible to do and will not be detected.

15. Will the operator be able to rectify the error?

One of the respondents simply answered yes to this question, the same person that answered "Dependent on error." to the last question answered: "What kind of error? If he/she orders full astern at the wrong moment there are physical constraints to what can be undone. The INS standard will explicitly suggest a kind of undo function in navigational equipment for correcting mistakes." to this question. One respondent referred to his previous answer, which was: "There are huge differences between systems concerning built-in-detection facilities.", he/she also said that it differs a lot. The last respondent answered maybe.

16. Are the operators trained to handle stressful situations?

Two of the respondents answered yes, while two said no.

17. Are they trained in emergency handling?

Two of the respondents answered yes, while two said no.

18. Do the operators go through periodical drills in emergency handling?

Two of the respondents answered yes, while two said no.

19. How much training is needed to operate the system?

Person 1: It is important to design system so that the emergency/ backup operation is as similar to the normal operation as possible. Then the transfer to backup systems will be less prone to mis-operation and errors and limit training requirements.
Person 2: Unknown
Person 3: Differs a lot from system to system and operator to operator
4 hours - 2 weeks
Person 4: For our system, the operator needs a couple of hours to go through the system.

20. Do the operators need frequent refreshment courses in order to be able to continue using the system? For example when coming back from a vacation or a off duty period on land.

Three respondents answered no, while the last answered yes.

21. Regarding emergency alarms in the system, would you say that there are too many, to little or just enough of them?

Person 1: Enough.
Person 2: The main problem is that it is difficult to assess the criticality of alarms, particularly when there are many of them.
Alarm patterns will be very different in different situations:
- Normal op: Irrelevant alarms take attention away
- Emergency: many alarms make it difficult to assess situiation
- Emergency: irrelvant alarms may distract.
Person 3: Far too many.
Person 4: It seems that all systems develop against more and more alarms and indications. I think it is too many alarms. It is very important the "real" emergency alarms don't "disappear" in the alarm jungle.

22. Are the most critical alarms easy distinguishable from the less important alarms?

Two of the respondents answered yes, while two said no.

23. Does the training ensure that the operator understands the task at hand?

Three of the respondents answered yes, while the last one answered no.

24. When the bridge system is in development, are the potential operators a part of the development?

Two answered yes, one answered no, while the last respondent did not answer at all.

25. How would you characterize the operator tasks?

Three of the respondents answered that the operator task is repetitive and routine, while the last respondent answered other.

26. If you answered other in the previous question, ot would like to elaborate, please do so here.

Person 1: -
Person 2: *The problem is that most of the time the ship sails straight forward and not much happens. Alarms that indicate a change in condition may be overlooked in this mode due to habit. In critical situations, the operator may need other information from the system than during normal operation. One example is that a status display may be more appropriate in an emergency than a more event based alarm list. While the opposite is true in normal operation.*
Person 3: *The execution of tasks depends on the phase of the voyage they may be very repetitive during certain phases of the voyage (which may last for weeks) while being the opposite in other phases.*
Person 4: -

27. Are you familiar with the ISO11064 standard, Ergonomic design of control centers?

None of the respondents were familiar with this standard.

28. Would you care to share you opinion on the standard mentioned in the previous question, and its uses?

None of the respondents answered this question.

29. Are you familiar with any standards regarding HCI (Human-Computer Interaction)? Please explain further.

Person 1: -
Person 2: *There are some standards in IMO and IEC that is required for ship equipment:*
- Resolution MSC.191(79) - Performance Standards for the Presentation of Navigation-Related Information on Shipborne Navigational Displays
- Code on alarms and indicators
- IBS/INS standard.
Person 3: *DNV G8 Human factors, DOT Human factors guide, ABS marine ergonomics, MSC.Circ.982*
Person 4: -

30. Would you care to share you opinion on the standard or standards you mentioned in the previous question, and its uses?

Three of the respondents chose not to answer this question. The last respondent answered the following: "These (and others) are fairly simple, but they are mandatory". This respondent was probably referring to his/her previous answer, which was: "There are some standards in IMO and IEC that is required for ship equipment: - Resolution MSC.191(79) - Performance Standards for the Presentation of Navigation-Related Information on Shipborne Navigational Displays, - Code on alarms and indicators- IBS/INS standard".

31. Are there any other issues you would like to comment further?

None of the respondents answered this question.

32. If you feel it is necessary to elaborate on the answers you've given in previous questions, please do so here.

None of the respondents answered this question.

33. Would you be willing to leave your phone number or e-mail address for me to contact you further?

One of the respondents left his/her e-mail address.