Ship Collision Risk

- An identification and evaluation of important factors in collisions with offshore installations

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Abstract
The risk for a ship collision is usually predicted to be one of the dominating risks for an offshore installation. The subject of this thesis originated in a need for continuous update and review of the models for assessing the collision risk, so that the technical development and management changes of today are reflected. The risk for collision is governed by the actions of the ship, which depends on several human and organisational factors that may be complicated to measure. The focus of this thesis therefore lies within the organisation of the ship, with the aim to identify and assess causes and underlying factors that contribute to a collision. This is undertaken by using a hierarchical model where the included components are assessed through expert judgement via interviews. The results from the interviews are combined with results from a literature review and the most contributing factors in a ship collision with an offshore installation are outlined. The results show that the three most contributing causes to the collision risk are if the officer on watch is absent, distracted or asleep.

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Executive Summary

An offshore oil installation is exposed to several types of risks and hazards such as explosions, leakages, fires, falling objects and collisions but the risk for ship collisions is usually predicted to be one of the dominating for an installation. According to many sources of statistics, the probability of collisions is not significant but it does however happen from time to time. The responsibility for ensuring compliance with legislative conditions lies on the organisation conducting petroleum activities and these conditions are often in form of a risk acceptance criterion for life safety.

There are numerous models developed to assess the risk for ship collisions with offshore installations, such as COLLIDE and CRASH. The models primarily originate from a previously made project with assumptions, technical equipment and management procedures on a ship that are not reflecting the advances in technology and operations of today.

The purpose of this thesis is to analyse why a collision with an offshore installation occur, however without any attention to the consequences of collisions. The ship is the focal point, considering its important role and how it is physically able to avoid colliding with an offshore installation by changing its course. It is noted that a great level of complexity lies within the organisation of ships; involving humans, technical equipment and decision making at several levels of the organisational structure. The area of grasping, assessing and quantifying human and organisational factors and its impact on accident scenarios is challenging, but necessary due to the recognised substantial impact in accidents. Another dilemma in assessments of actions and human errors is how humans are not predictable and that accidents often occur as several steps linked together in a chain of events.

A principle within this thesis is an application of the system approach when working towards a structure that overviews a collision scenario. By using a success scenario approach, an identification of components in a collision was established by adopting theories and findings from literature, accident statistics, risk analysis models and hazards identifications through workshops. The process resulted in a structural model with three different levels including scenarios, primary causes and underlying factors. By applying this model, an outline of the chain of events was created with several components that together may result in a collision. The identified components were evaluated by using expert judgements during interviews together with conclusions from research.

Part of the results from the evaluation was that the most contributing scenario to the collision risk appears to be a lack of awareness on the ship, followed by handling errors and ship specific technical problems. The most influential primary causes to lack of awareness are; the officer on watch being asleep, distracted or absent. The results may be used as a background to further research concerning collision risks, so that a thorough update of the risk analysis models can be completed. The thesis also indicates how important it is to review risk analysis models continuously with regards to changes in organisations, equipment and environmental conditions. The conclusions can furthermore provide input to where significant hazards lie within the maritime industry, to be adopted in risk analyses or work place safety assessments. An enhanced appreciation of the uncertainties involved in assessment of human and organisational factors may also be achieved.

Sammanfattning (Summary in Swedish)

En offshore installation utsätts för flera olika typer av risker och faror som t.ex. explosioner, läckage, bränder, fallande objekt och kollisioner varav risken för kollision ofta beräknas vara en av de största. Enligt statistik från flera källor är dock sannolikheten att en kollision inträffar inte signifikant men det händer ändå då och då. Organisationen som ansvarar för offshore installationen ska se till att regelverk följs vilket ofta innebär att riskacceptanskriterier för personsäkerhet ska uppfyllas.

Det finns flera modeller som utvecklats för att beräkna risken för fartygskollisioner med offshore installationer varav två exempel är COLLIDE och CRASH. Modellerna är till stor del baserade på ett tidigare gjort forskningsprojekt där antaganden, teknisk utrustning och rutiner inom organisationen på ett fartyg inte återspeglar utvecklingen som skett inom dessa områden fram till idag.

Syftet med examensarbetet är att analysera varför kollisioner med oljeplattformar inträffar, dock utan att gå vidare in på konsekvenserna av en kollision. Fokus ligger på fartygets agerande eftersom detta har möjlighet att undvika en kollision genom att ändra kurs. Organisationen på och kring ett fartyg är komplicerad och involverar människor, teknisk utrustning och beslutsfattande på flera olika nivåer. Att förstå, värdera och kvantifiera mänskliga och organisatoriska faktorer samt deras påverkan på olyckor är en utmaning men också nödvändigt då denna påverkan anses vara stor. Människor är inte förutsägbara och olyckor beror ofta på en kedja av händelser vilket ytterligare försvårar en värdering.

Den övergripande strukturen i ett kollisionsscenario har utvecklats med utgångspunkt i en systemsyn.Genom att utgå från ett ”success scenario” i kombination med information från litteratur, olycksstatisk, riskanalysmodeller och faroidentifiering genom workshops har olika komponenter i en kollision identifierats. Detta resulterade i en modell med de tre nivåerna; scenarier, primära orsaker och underliggande faktorer. Genom att använda modellen skapades en översiktlig bild av de komponenter som tillsammans bidrar till en kollision. De identifierade komponenterna värderades genom intervjuer med experter i kombination med resultat från litteratursökning.

Resultaten visar bland annat att brist på uppmärksamhet/medvetenhet verkar vara det mest bidragande scenariot till risken för kollision. Direkt felhandlande och tekniska fel på fartyget kan också vara bidragande men i samma utsträckning. Bristen på uppmärksamhet/medvetenhet beror oftast på att vakthavande befäl har somnat, är distraherad eller är frånvarande från bryggan.

Riskanalysmodellerna för kollisioner mellan fartyg och offshore installationer kan uppdateras genom att resultaten används som bas för vidare forskning inom kollisionsrisker. Resultaten visar också på hur viktigt det är att uppdatera riskanalysmodeller regelbundet eftersom det sker förändringar i organisationer, utrustning och den omgivande miljön. Förutom detta kan resultaten även användas inom riskanalyser och säkerhetsarbete inom sjöfarten genom att visa var de största problemen finns. Förhoppningsvis kan också förståelsen för osäkerheter i allmänhet öka, speciellt när det gäller bedömning av mänskliga och organisatoriska faktorer.

TABLE OF CONTENTS

1 Introduction

This chapter provides the background of the thesis, outlines the purpose and research questions and define delimitations.

This master thesis is the concluding part of the Master of Science Programme in Risk Management and Fire Safety Engineering at Lund University, Sweden. The thesis has been written in association with the Department of Fire Safety Engineering and Systems Safety in Lund and Det Norske Veritas (DNV) in Oslo. The project has been developed during a period of 20 weeks.

1.1 Background

"The ninth of July 2007 one of the most serious incidents of the year occurred when the vessel Bourbon Surf collided with the offshore installation Grane. The situation was close to result in catastrophic consequences for the installation and the number of failure scenarios linked together prior to the collision was remarkable.

The Petroleum Safety Authority (PSA) has rarely been presented with a scenario including such a considerable number of failures at the level of seriousness as were described by the shipping company Bourbon Offshore in October 2007:

- *Both the captain and the master left the bridge at a critical time when the ship was on its way towards Grane and the vessel continued at autopilot without any watch keeping.*
- *The waypoint of the ship was set directly at the offshore installation.*
- *There was no contact between the vessel and the installation during the approach, even though the prescription calls out for this.*
- *The schedule for entering the safety zone was not filled out.*
- *The captain misinterpreted the speed of the vessel and the distance to the installation, hence the speed of the vessel exceeded the restrictions.*
- *The responsibilities and the roles between the captain and the master were unclear, the communication was questionable and the captain was not in control of the vessel in a critical phase. "*

(Freely translated from PSA, 2008b)

As described in the accident scenario above, collisions between ships and offshore installations do occur even though there have been amazing improvements within the maritime sector considering technical equipment, training and management procedures (Wang & Zhang, 2000; Lützhöft & Dekker, 2002). So, why do collisions still occur? A great level of complexity lies within ship organisations, a system which involves humans, technical equipment and decision making in several different parts of the organisational structure. There is without doubt a need for identifying the underlying reasons of a collision, so that a greater understanding of why collisions occur can be achieved and future accidents avoided.

The consequences of a collision depend on characteristics such as the type of vessel, the speed, where on the installation the ship hits etc. The collision can in a worst case lead to a total collapse of the offshore installation resulting in fatalities, environmental damages and high economic costs.

When discussing offshore installations within this thesis, several types of objects involved in petroleum activities are included. Fixed platforms, floating installations, semi-submersibles, jack-ups and floating production, storage & offloading (FPSO) units will all be taken account of in the expression offshore installation.

An offshore installation is exposed to many types of risks and hazards, such as explosions, leakages, fires, falling objects and collisions (Harstad, 1991). Statistics show that approximately 10 percent of the annual damage cost for an offshore installation is related to collisions (DNV Technica, 1995). An analysis of incident records (1975-2001) of the United Kingdom Continental Shelf (UKCS) shows that the mean incident collision frequency is 0.24 per year for collisions (HSE, 2003). The most frequent type of collision involves supply vessels that are designated to reach an offshore installation, but for some reason collide with the installation. These incidents generally have minor consequences due to decreased speed etc. but some rare events have occurred with considerable consequences (HSE, 2003). Other vessel types that pose a risk are for example merchant ships, fishing boats, stand-by vessels and navy vessels, out of which merchant ships are likely to cause considerable consequences due to characteristics such as size and speed.

The risk for ship collisions is usually estimated to be one of the dominating risks for an offshore installation (HSE, 2003). Whether this depends on the actual risk being governing or the models for assessing collision risks not reflecting reality well enough is left unsaid. However, without commenting the statement further, this shows a great relevance of the area of research. There is also a need to update the models to reflect the technical development and management changes of today, when considering that many of the base assumptions of the models originate from the 1980's.

1.1.1 Association with DNV

DNV is regularly working with clients from the offshore industry, e.g. performing risk assessments of new developments of oil and gas installations or assessing changes that are requiring an updated risk assessment, to correctly reflect the existing risk picture.

There are several different research projects within DNV with an aim to further develop the models used for analysing collision risks. The projects are spanning from extensive consequence modelling to establishment of valid ship data and statistics. The subject of this thesis originated in a need within DNV for continuous update and review of the models used when assessing the collision risk for an offshore installation.

1.2 Problem definition

First of all, the focus of this thesis mainly lies within the boundaries of the ship and not the installation due to where the primary possibility to avoid a collision exists. Above all, it is the ship that is physically able to avoid colliding with an offshore installation by changing its course. A non-fixed offshore installation may be capable of changing location, but this is in most cases such a timely and high risk operation that must be initiated at a very early stage and means a significant production loss. This may therefore not be a likely measure to take. A full evacuation of an offshore installation is considered to last approximately 30 minutes (PSA, 2008a). Prior to this, the crew has to obtain awareness of a potential collision risk and initiate evacuation. A long duration of this phase depends on factors such as the difficulty to identify a vessel as a risk at a long distance, high ship density etc. The risk for ship collisions is generally perceived as small amongst employees at offshore installations, when compared to other hazards such as leakages, explosions and fires (PSA, 2008a). This view may prolong the time before awareness is reached. Also, to relocate an offshore installation does not necessarily mean risk avoidance, considering that the ship hypothetically could change its course in the same direction.

One of the most complicated areas to measure and quantify is human and organisational factors and its impact on accident scenarios is known to be substantial (refer to Section 3.1). The collision risk models do generally not seem to consider errors with organisational and human background in such a comprehensive manner necessary to provide reliable applicability.

Another matter to query is discovered when looking into the input data used when conducting an analysis. Numerous inputs consist of expert judgements based on assumptions, technical equipment and management procedures that were relevant for the time of the judgement. There have been gradual changes since the models were created and an update is therefore necessary, to more accurately reflect the current conditions.

It is shown in accident databases that a very limited number of collisions with offshore installations have occurred worldwide (e.g. HSE, 2003). There are therefore many difficulties with estimating the probability of a collision when only using statistical data as the foundation, given the few accidents that have occurred.

Bearing in mind the reasoning above, there are some significant weaknesses with the existing methods that are used to assess collision risk. More background information to the problem definition will be provided in Chapters 2-6 which also gives more context to the delimitations.

1.3 Purpose

The overall purpose of this thesis is to evaluate factors that are affecting the risk for a collision between a ship and an offshore installation. This will contribute to a better understanding of which factors should be included in a collision risk analysis and how important these factors are. The results from this study should be possible to use for companies and organisations that deal with collision risk analyses. The results should also provide guidance and support risk control measures that are to be undertaken.

The principal target group of this thesis is people working with collision risk analysis in the offshore industry and in the maritime sector.

1.4 Research questions

The research questions that need to be resolved to obtain the purpose of this thesis are:

- What are the primary causes and underlying factors behind a ship collision with an offshore installation?
- To what extent do these identified primary causes and underlying factors contribute to the risk for a collision?
- How can this deeper understanding of collisions be used, both integrated when assessing collision risk and generally in the maritime sector?

1.5 Delimitations

Several delimitations have to be made due to the limited time available of the master thesis. Only collisions between ships and offshore installations will be examined, not collisions with other kinds of installations or collisions between two ships. The thesis will look closer into models that are used to predict the frequency for the collision risk and will not discuss the consequences because how the methods to assess frequency and consequence for a collision generally are separated. There are also several sources of research that deals with the structural impairment subsequent a collision. As described in the problem definition above, an assumption considering the possibility of the offshore installation relocating to avoid a collision is disregarded. Intentional collisions such as terrorism where a vessel aims to collide with an offshore installation are only briefly discussed. Similarly, direct technical problems that may cause a collision, e.g. steering failure, are only concisely touched upon. The study excludes collisions between offshore vessels and their dedicated offshore installations and also collisions with submarines. The organisation, procedures and patterns of movement of both offshore vessels and submarines adversely diverges from other passing vessels and this thesis is therefore not applicable to these vessel types.

1.6 Disposition

The thesis is divided into four parts to easily give an overview of the scope of work and also to facilitate if a reader has an interest in a specific section. Several chapters are concluded with reflections, which consist of the thoughts of the authors if nothing else is mentioned.

Part 1 comprises chapters 1 - 2 and provides a background, expresses the purpose of the thesis and summarises the research questions. In addition, the methodology used in the thesis is outlined and related to scientific settings.

Part 2 contains chapters 3 - 6 where important concepts and theories are described followed by a more specific introduction to the maritime and offshore industries and to risk assessment within the offshore sector.

Part 3 consists of chapters 7 - 8 and presents the identification and assessment of identified components in a collision scenario together with a summary of the results from expert judgements.

Part 4 includes chapters 9 - 10 with a discussion of the results, conclusions and recommendations for future work.

2 Method

This chapter describes some of the thoughts behind the choice of method and gives a brief summary of the work process of the thesis. The text is complemented by an illustration that shows the interactions between the different parts of the work process (refer to Figure 1, p.10).

2.1 Scientific perspective

To make sure that research can be useful and beneficial to others, it is very important to be scientific. If scientific methods and ways to express results are applied, validation will be possible and the results can therefore be applied in other contexts, hence facilitate communication between people (Backman, 2008).

To achieve scientific research, it is necessary to pursue reliability, validity and objectivity (Ejvegård, 2008). Validity considers if what is supposed to be measured really is measured. Reliability describes how reliable the way of measuring is, e.g. the repeatability of the method. Low reliability always leads to low validity. Objectivity takes into account how neutral projects are and if all views of the problem are considered. (The University of Gothenburg, 2008)

There are three statements that referees of scientific articles use and that contribute to the achievement of validity, reliability and objectivity. It should be possible for readers of a research report to:

- Repeat the examination
- Evaluate methods, observations and results
- Understand the intellectual process

(Luleå University of Technology, 2008)

These statements are kept in mind during the development of the thesis which hopefully has resulted in a transparent project that is easy to follow, understand and evaluate.

It is possible to measure validity and reliability in numerical ways if quantitative methods are used (The University of Gothenburg, 2008). An endeavour to achieve validity is possible in qualitative studies, but it is however unlikely that the validity of a qualitative measuring instrument will be as categorically laid down as a quantitative instrument (The University of Mälardalen, 2008). The validity in qualitative studies is rather focused on how work is accomplished and the effort put into it than the method used (Golafshani, 2003).

The method of this thesis is classified as quantitative, but with a qualitative approach. When it comes to the assessment of factors, questionnaires, scales and numerical methods are used, which traditionally are signs of a quantitative method (Backman, 2008). The purpose is however more focused on contributing to a fundamental understanding of the most important factors in a collision than trying to evaluate probabilities of these, which makes the approach more qualitative. In addition to this, the basis of the assessment is an evaluation of causes and underlying factors undertaken through literature reviews and discussions, also normally seen as qualitative methods (Backman, 2008).

2.2 Work process

This section describes the work process and discusses both the way towards a definition of the purpose and the phases that led to completion of the project.

2.2.1 Decision of purpose and research questions

The overall purpose was from the beginning to evaluate and update the existing models that are used to assess the risk for collisions between ships and offshore installations. Due to the large extent of that purpose, delimitations had to be made. A comparatively large amount of time during the first weeks was spent evaluating the models for collision risk that are used at DNV, so that a more specific purpose could be outlined. After the review of the models, a focus on the actions of the ship in a collision scenario was decided, mainly for the reason of the crucial role the ship plays in a collision and the necessity to update this part of the model.

2.2.2 Literature and contacts

Literature and contacts are essential parts of the work. Reading of literature has been an on-going process from start and almost to the end, of course with different focus areas during the progress of the thesis.

The literature review started with a rather unspecified search for relevant information. Keywords when searching for literature were for example: offshore, ship, collision, risk analysis, QRA, HRA, human error, organisational factors and oil platform. The goal was to reach a deeper understanding of the subject and be able to make delimitations and come to a decision on research questions.

Some of the risk analyses recently undertaken by DNV were studied, which helped to identify important assumptions and limitations that are included in a collision risk analysis. It also gave an understanding for how the analyses are performed today.

Due to the global nature of shipping, research within the area is spread all over the world. The sources of information are many and divided, both geographically and between different types of organisations. This contributes to difficulties when trying to get an overview but also provides numerous independent sources and diverse views of the area.

The information about safety management, organisational factors and human errors is almost never-ending, especially when it comes to theoretical approaches and how to divide factors into separate groups. Primarily literature closely linked to the maritime sector was selected. Existing research does not often discuss collision risks for offshore installations, but more frequently focuses on collisions between two ships, ships and wind farms or other kinds of accidents such as groundings.

Except from the articles, reports and books found through different search engines, a lot of useful information was received from contacts within DNV. Universities with relevant education programmes and with organisations that work within the maritime and offshore sectors have also been sources of information.

2.2.3 Evaluation and measurement of factors

From the literature review in combination with workshops and brain-storming, a selection of causes and underlying factors that contribute to the risk for collisions could be completed. In the workshops, a hierarchical model was used as a starting point with a collision as the top event. On the basis of the model it was possible to work out a logical connection between the identified scenarios, primary causes and underlying factors. A more thorough description of this process can be found in Section 7.1.1. When the structure had been set up, it was presented to people working in the maritime sector at DNV.

The evaluation of factors was done in assistance with experts through interviews. The interview guide was tested by one risk analyst within the offshore sector, one risk analyst within safety and one psychologist working with human factors. This was done to achieve a material that was workable and comprehensible.

There are several benefits with using exert judgement, considering the possibilities to embrace new knowledge and assess areas that are difficult to analyse by only using statistics. Expert judgements have been used in several projects within the area (Technica, 1987; HSE 1999; Soma, 1999).

The initial plan was to assess the first two levels of the structural model, i.e. the scenarios and primary causes that can lead to a collision, with a short questionnaire and value the underlying factors through interviews. The reason to why a questionnaire was chosen for the primary causes but not for the underlying factors was mainly because the primary causes are quite easy to understand without explanations. The underlying factors are more complicated to explain in a short and consistent way. By ranking the primary causes in a questionnaire and not only in interviews, the advantage of many respondents for the primary causes could have been achieved. The questionnaire was sent to ship captains and last year students at maritime colleges but due to low response frequency, the questionnaire was not used when compiling the results. To make sure that the results would be valid, the initial aim was to receive approximately 100 answers, however only 40 questionnaires were returned in the end.

Scenarios, primary causes and underlying factors were instead evaluated through interviews. The interviews were following an interview guide with a layout as a questionnaire (refer to Appendix A). The selection of participants in interviews is of great importance, especially when the number of respondents is limited. A list of participants in interviews can be found in Appendix B.

The results from the interviews were brought together and then compared with previous research found through the literature review. Conclusions could be drawn from the analysis and recommendations for future work were made.

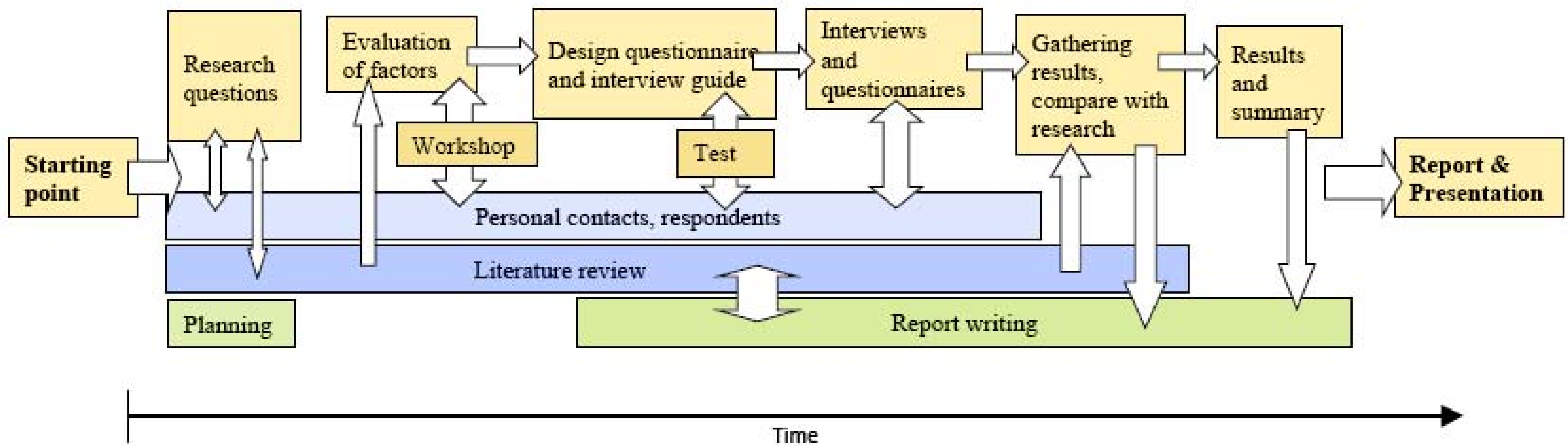


Figure 1: An illustration and overview of the work process with respect to its distribution over time. The arrows show the flow of information between the different phases.

3 Human and organisational factors

This chapter provides the basis for our view on human and organisational factors. Definitions of concepts that are regarded as important for the understanding of this thesis will also be given.

3.1 Introduction

Even before the 19th century, human error was identified as one of the primary factors contributing to casualties at sea. The research about human factors increased with the World War II and the positive results provided the impetus for further research in the area of maritime human factors. Since then, there has been substantial development and human factors are currently integrated in the regulations from the International Maritime Organisation (IMO) through for example the ISM-code and the STCW-convention. (Grech et al, 2008)

Today, research about the subject is or has been conducted by for example IMO, the Health and Safety Executive (HSE) in the UK and universities (e.g. Norwegian University of Science and Technology and Lund University). Accident databases and reports from for example the Swedish Accident Investigation Board also tend to provide more detailed information about causes of accidents than before.

Human factors are very often mentioned as the most common cause to accidents, but its contribution varies in different sources from 46 % to 85% of the accidents (Baker & Seah, 2004). The holistic view together with definitions of human factors and human errors play a vital role with regards to how these can be used in research, preventive measures etc. The definitions are though very seldom mentioned in research articles and accident reports. This lack of a scientific definition of the human factor makes it difficult to interpret the findings (Marine Profile, 2008).

3.2 Different views

There are two basic ways to look at human errors; the personal approach and the system approach. The personal approach focuses on unsafe acts as results from deviant moral processes. The system approach regards human errors as consequences rather than causes and that human errors mainly have an origin in systemic factors. A basic statement of the system approach is how human conditions are impossible to change, but the conditions under which humans work can be altered. Defences and barriers are key elements in the approach. (Reason, 2000)

The system approach is used as a basis for the evaluation of causes and underlying factors to the collision risk in this thesis. The system approach has been chosen, mainly because of a belief in the approach but also because this is the outstandingly dominating approach in the literature. It does however seem like the personal approach is more often applied in practice than in theory.

Reason (2000) illustrates the system approach with a sliced Swiss cheese where the holes in the cheese represent failures (Figure 2). For an accident to occur, failures usually need to happen at different levels and together be linked as a chain of events ending in the incident. The presence of a hole in one barrier does normally not cause an accident, each barrier serves as a defence or a preventive measure.

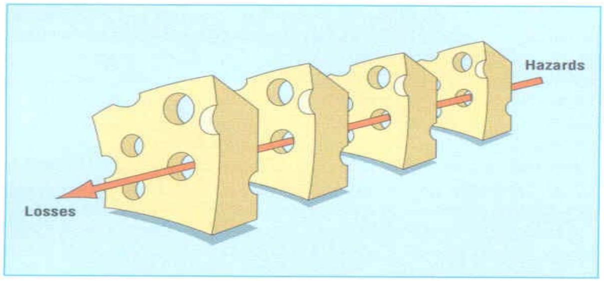


Figure 2: The Swiss cheese model (Reason, 2000).

The holes in the barriers arise for two reasons: latent conditions and active failures. Latent conditions are those that do not immediately degrade the operation of a system but can lead to an accident if combined with other events, for example active human errors (Embrey, 1992).

Active failures are unsafe acts committed by people who are in direct contact with a system. The active failures have an immediate and usually short lived impact on the integrity of a defence. An analogy can be made where active failures are described to be like mosquitoes.

"They can be swatted one by one, but they still keep coming. The best remedies are to create more effective defences and to drain the swamps in which they breed. The swamps, in this case, represent the ever present latent conditions."
(Reason, 2000)

Latent conditions can be identified and dealt with before an adverse event occurs, while active failures often are more difficult to foresee.

It is very important to realise that humans not only contribute to failures but are also handling a lot of problematic situations. A feasible solution is hardly to replace all humans with technical equipment; humans are still more adaptive to different environments and situations with creativity when it comes to solving problems.

3.3 Categorisation and definitions of factors

The system approach means that not only the human as an individual is affecting the possibility for a failure that is categorised as a human error in for example an accident report. Human errors are also influenced by the surroundings through legislation, organisational culture, environment, design etc.

The connections between these different elements have been illustrated as a socio technical system, for example by Koester through "The Septigon Model" (Figure 3). The socio technical system model aims to focus on the relationship between people and technology. Grech et al. (2008) mean that it is obvious that organisations in the maritime domain are consistent with the socio technical systems perspective and that ships can be analysed as a combination of technology (the vessel, engine, equipment, instruments etc.) and a social system (the crew, their culture, norms, habits, custom, practices etc.).

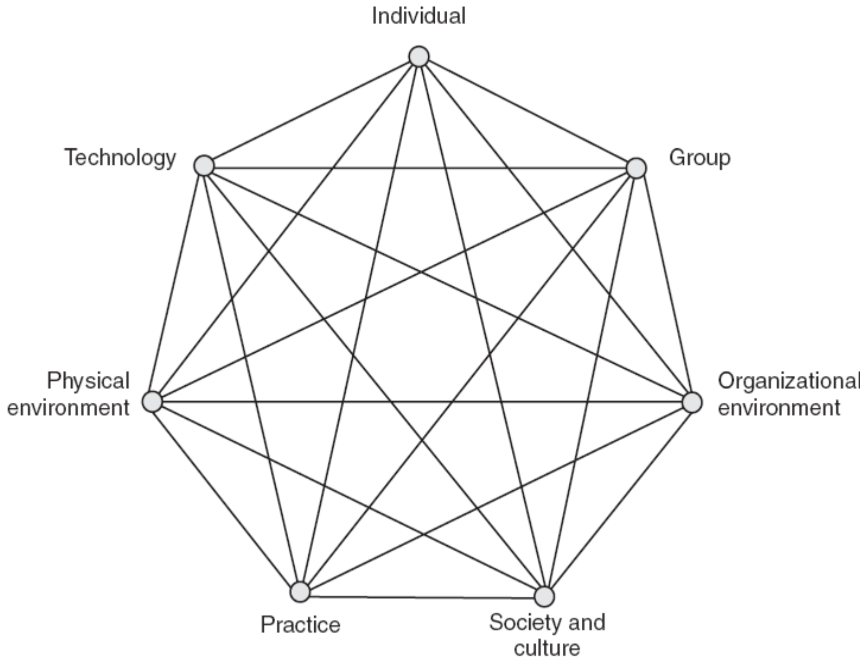


Figure 3: “The Septigon Model” by Thomas Koester (Grech et al. 2008).

Another illustration of the connection between different elements has been prepared by Embrey (1992). This generic model is called MACHINE (Model of Accident causation using Hierarchical Influence Network) and shows how the direct causes of all accidents are combinations of human errors, hardware failures and external events (Figure 4).

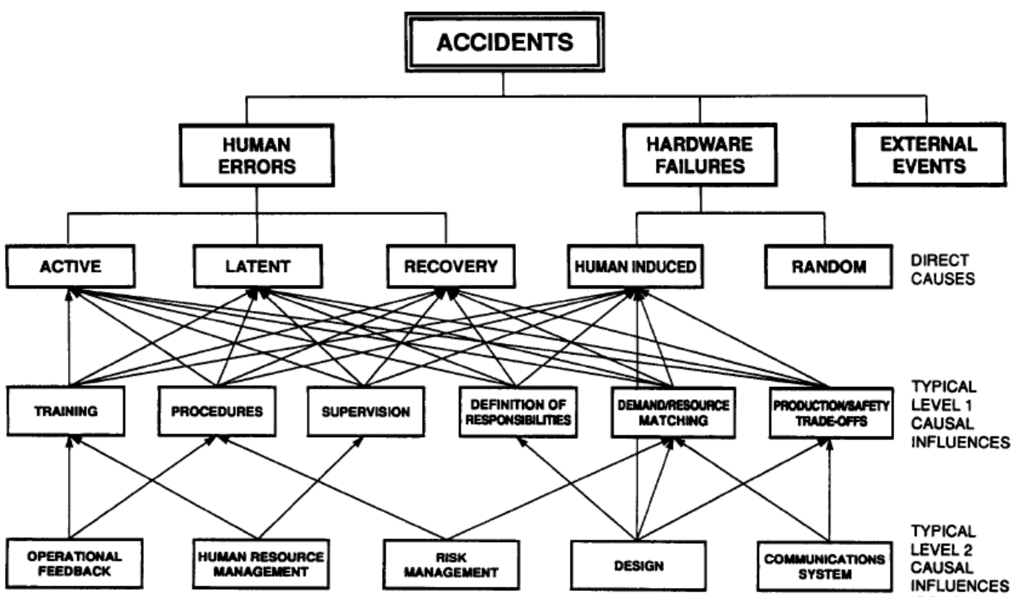


Figure 4: The MACHINE model reflects the relationship between humans, technology and environmental elements (Embrey, 1992).

These two models are just a small selection of the theories found in the literature. There are several different categorisations and groupings of human and organisational factors that all aim to clarify the connections between humans and the surrounding environment.

Most research projects focus on a narrow area, maybe just one specific contributing factor, and are therefore not forced to deal with the problem of categorisation in the same way as projects that span over a larger extent. The correlation between factors can sometimes make it difficult to decide the origin of a failure. The borders between different categories or elements, e.g. human factors, organisational factors and technical factors, are far from fixed and it is not always obvious which category a specific factor belongs to.

3.4 Definitions

As mentioned before, the concept human factor is very seldom defined in literature, which increases the likelihood that different interpretations of the concept are used. This problem is closely connected to the discussion above about categorisation. If someone fails using the technical equipment, is the problem technical or human? Does the failure depend on the design of the equipment or because the user does not know what button to press?

There are no black or white answers when dealing with human and organisational errors, rather a field with different shades of grey. The causes of a failure can be many and most of them are, as shown in Figure 4, connected to each other. In one way or another, humans are always the cause of a failure because they design technical equipment and form organisations. But there need to be a distinction somewhere, where should the line be drawn?

Concepts within this thesis are defined as follows. The definitions are not comprehensive but they will hopefully give some guidance.

Human factor - The scientific discipline of understanding the interactions among humans and other elements of a system and also the profession that applies theory, principles, data and methods to design in order to optimise human well-being and overall system performance (IEA, 2008). Human factor is sometimes used synonymously with ergonomics even though ergonomics is a subset of human factors (Grech et al, 2008).

Human error – An inappropriate or undesirable human decision or behaviour that leads to unwanted outcomes or has significant potential for such an outcome (Grech et al, 2008).

Dekker (2002) views human error on the basis of three factors that all contribute to the definition:

- Human error is a symptom of problems deeper inside the system.
- Human error is systematically connected to features of people’s tools, tasks and operating environment.
- Human error is not the conclusion of an investigation, it is the starting point.

The expression “human error” is used in situations when the reason is primarily related to human behaviour. Underlying factors to the primary causes can be organisational, human or technical but the primary cause is still the acts of an individual.

Organisational factor – A factor connected to a corporate responsibility reflected by a team or a group of individuals, consciously or not.

Technical failure – A failure that is not affected directly by humans in the specific situation. This can for example be a production failure that arises during the usage of equipment but not related to the user.

3.5 Measuring human and organisational factors

Human and organisational factors are not easy to measure and quantify because of their very nature. They are living elements and are to a large extent based upon subjective thoughts and ideas.

There are difficulties and uncertainties involved when assessing human and organisational factors in a quantitative way. It should also be taken into consideration if there even is a purpose of quantification. It can be misleading to quantify factors that are challenging to estimate, especially when the values are going to be used in a bigger perspective and maybe even without a complete definition and explanation.

The different methods available for measuring human and organisational factors are many and almost impossible to overview. Most methods are adjusted to the purpose of the specific survey. Examples of methods used are THERP, HEART and SLIM (Grozdanović & Stojiljković, 2006). Data and statistics used in the methods are usually based on expert judgement or statistics from accidents and near misses.

Even though there is a great complexity in trying to quantify human and organisational factors, ignoring the topic is not a feasible way. Human and organisational factors must be taken into consideration somehow and the impact should be reflected in risk analyses that concern systems involving humans.

4 Interaction between the maritime and offshore industries

This chapter aims to briefly touch upon the maritime and offshore sectors including applicable legislation. Following this is a part about incidents within shipping and the last section is a discussion of the dilemma with using accident statistics when assessing the collision risk between ships and offshore installations.

4.1 Maritime traffic – setting the scene

Shipping and seafaring is one of the oldest industries in the world and also very important by carrying 97 percent of the world trade (Wang & Zhang, 2000). The industry is international and it is common with crews of various nationalities including different languages.

All ships have a flag state, which is a regional policy making authority within each country that upholds the international legislation (Maritime & Coast Guard Agency, 2006). See also Section 4.2.1 that presents legislative requirements.

There are various types of ships within the industry and maritime work can be defined as any kind of work performed onboard any kind of vessel (Grech et al, 2008). Five maritime work tasks can be defined:

Navigation: route planning, track keeping and collision avoidance.
Propulsion: the responsibility for the integrity of the ship's propulsion system and associated auxiliaries.
Cargo handling: loading, keeping the cargo (including passengers) in good condition, and unloading.
Vessel maintenance: keeping the ship, its equipment (e.g. the auxiliary equipment) and the crew in operational condition.
Ship management: allocation of tasks and responsibilities, control and supervision, and communication.
(Bertranc, 2000)

As within every type of business area, there are vast differences in organisational cultures in the companies of the shipping industry. There also exists a lot of research concerning safety culture and organisational culture in the maritime industries (PSA, 2008a; Kristiansen & Soma, 1999; Håvold, 2007).

As summarised above, one of the essential components within shipping is navigation. Navigational accuracy is limited and wind/waves may give deviation of several nautical miles. GPS (Global Positioning System) is very common on all boats except for smaller vessels (US Coast Guard, 2008). AIS (Automatic Identification System) has been enforced by the International Maritime Organisation (IMO) and is required for all vessels that may pose a risk to offshore installations. These are examples of the great development and several new aids that benefit the shipping industry. The systems improve both the navigational accuracy and the possibility of easier accessing contact information of vessels, hence increasing the likelihood of successful warning in a collision scenario.

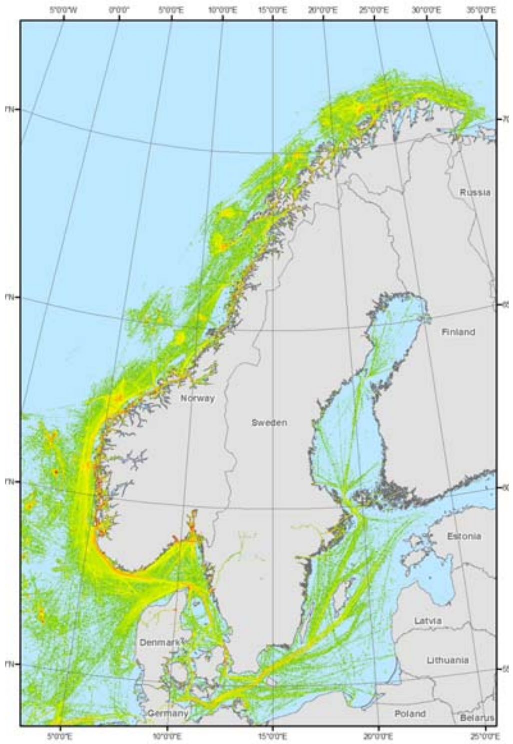


Figure 5: An overview of ship traffic in Scandinavia, recorded with AIS (DNV, 2008).

Figure 5 shows ship traffic in the Scandinavian area, gathered from AIS data. The figure describes the regular shipping patterns in the waters of the Norwegian Continental Shelf, shown as shaded areas outside the coastlines.

Every company is obliged to ensure that the master, officers and ratings do not work more hours than is safe in relation to the performance of duties and the safety of the ship (IMO, 1999). There should for example always be two people on the watch during night time and in bad weather (IMO, 1995).

The type and size of a ship is reflected in the structure of the organisation, both in the company and on the vessel itself, by affecting how the watches are divided, manning levels etc. A large passenger ship will presumably have at least two people on the bridge while small fishing vessels often have minimum crew levels that are supposed to both manage watch keeping on the bridge and perform tasks on deck. The manning level of a vessel would most likely affect the type of watch system that is applied. The size of the shipping company and the organisational structure affects the organisational culture, acceptance and how well procedures are implemented. Ships also have different patterns of movement. Ships in regular traffic are expected to follow historical shipping routes while fishing boats follow the motions of their catch.

All vessels must be stand-by on the VHF (Very High Frequency) channel 16. This open and international way of communication is restricted to relevant and safety related communication (Swedish Maritime Administration, 2008a). Irrelevant communication is forbidden, but may unfortunately be common.

Authorities

The Norwegian Maritime Directorate (NMD), known as Sjøfartsdirektoratet in Norway, influences the Norwegian stands on shipping matters and legislation in an international perspective. The directorate has jurisdiction over ships registered in Norway and foreign ships arriving in Norwegian ports. The directorate's main goals are to prevent accidents and to achieve a high level of safety for lives, health, vessels and the environment. (NMD, 2008)

The International Maritime Organisation is the maritime organisation within the United Nations, with the key task to develop and maintain a comprehensive regulatory framework for shipping globally. The IMO sets the international standards that later on are reflected in the national legislation. This includes safety, environmental concerns, legal matters, technical co-operation, maritime security and the efficiency of shipping. The IMO provides conventions such as SOLAS, MARPOL and the ISM code that establishes the minimum level of safety on a ship. There is also an international standard for training, certification and watch keeping for seafarers (STCW). (IMO, 2008)

4.2 The oil and gas industry

The oil and gas industry started in Norway in the late 1960's with the discovery of the Ekofisk area (NPD, 2008a). Figure 6 **Figure 6**illustrates the location and density of the oil and gas fields in the Norwegian continental shelf.

The petroleum industry in Norway involves production in form of both oil and gas and is now the dominating business area in Norway by providing approximately a third of the national income. There are 57 fields of production in the Norwegian Continental Shelf in 2008. Norway is presently the fifth largest oil exporting country and the 11th largest producer in the world. (NPD, 2008a)

All offshore installations are surrounded by a safety zone that extends 500 metres from any part of the installation. Ships are not allowed to enter the zone. (HSE, 2008)

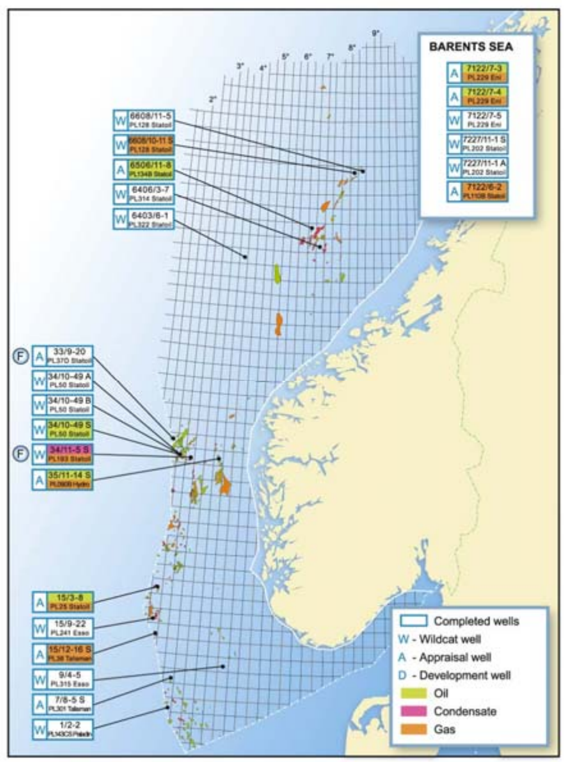


Figure 6: Location of the offshore installations 2006 (NPD, 2008b)

4.2.1 Legislation

The legislative framework provides the conditions for layout and location of offshore installations and requires risk analyses to be performed so that a certain level of safety can be ensured. There has been great development and adjustment to the surrounding conditions in the offshore industry. Norway has, together with the UK, been the proceeding country with regards to legislation and new, innovative ideas. The authorities have progressively changed the legislation towards being goal oriented and performance based, when compared to the previous more specific and prescriptive requirements (Aven & Pitblado, 1998; Smith, 1995; Friis-Hansen & Simonsen, 2002).

Authorities

The main authority that provides legislative conditions for petroleum activities in the Norwegian Continental Shelf is the Petroleum Safety Authority (PSA), which is referred to as Petroleumtilsynet (Ptil) in Norwegian. PSA is the governmental body for technical and operational safety including emergency preparedness and for the working environment (PSA, 2008c).

In addition to the international and Norwegian jurisdiction, the authorities in the UK also play an important role due to its geographical location. The Health and Safety Executive (HSE) is the governmental body in the United Kingdom that aims to protect people against risks to health or safety, arising out of work activities. This is achieved through research, information and advice, promoting training, inspection, investigation and enforcement. (HSE, 2008)

Overview of historical background

The legislation restricting the oil and gas production industry has its starting point in quantitative risk assessment (QRA) that originated in the probabilistic risk assessments developed in the nuclear industry in the USA (Vinnem, 2007).

QRA was introduced in the offshore industry in Norway in the late 1970's. This was followed by guidelines for safety evaluation of platform conceptual design in 1981, requiring that a QRA was completed for each installation. The document presented a fixed risk acceptance criterion for life safety that was set to 10^{-4} per platform year as the legitimate frequency of accidents (Aven & Vinnem, 2005). Following this development, Norway was the only country requiring a QRA until it became mandatory in the UK as well in 1988, following the Piper Alpha incident.

Existing legislation

Since 2004 the Petroleum Safety Authority (PSA) has issued five regulations that control safety of design and operation of offshore installations:

1. Regulations relating to health, environment and safety in the petroleum activities (the Framework regulations)
2. Regulations relating to management in the petroleum activities (the Management regulations)
3. Regulations relating to design and outfitting of facilities etc. in the petroleum activities (the Facilities regulations)
4. Regulations relating to conduct of activities in the petroleum activities (the Activities regulations)
5. Regulations relating to material and information in the petroleum activities (the Information duty regulations)

(PSA, 2008d)

In addition to the regulations described above, the NMD Risk Analysis Regulations require that a risk analysis is completed for all mobile units. This applies to all vessels that are registered within the Norwegian register of ships.

The legislative frameworks are now similar in the UK and Norway. However, one noteworthy difference is how the risk analyses in the UK only are applied to assess life safety and not environmental and asset risks.

Risk acceptance criteria

There are two main categories of risk acceptance criteria related to personnel risk that are commonly used in the Norwegian and UK continental shelves. Firstly, there are absolute values that state that the likelihood of a certain consequence shall not exceed a fixed number, such as the acceptance criterion of 10^{-4} as previously mentioned. Secondly, statistical expected numbers of fatalities per 100 million exposed hours (i.e. the FAR value) is applied within the industry (Aven & Pitblado, 1998).

Using definite risk criteria that are pre-determined can result in assessments having the wrong focus and purely aim to meet the criteria rather than achieving overall good and viable design solutions (Aven & Vinnem, 2005). It is possible that having specific risk acceptance criteria may lead to “number-crunching” in the areas that are considered easily quantified whereas significant areas such as human factors are treated more vaguely due to the difficulties in accurate quantification. But these types of problems may also exist if risk acceptance criteria are defined after a risk analysis is completed.

Practice

There is a clear outline of roles concerning safe management within the offshore industry. The key principle of the safety regime in Norway is that the entire responsibility for ensuring compliance with legislative conditions is on the organisation conducting petroleum activities (Aven & Vinnem, 2005). In addition to this, the authorities supervise that the management systems are providing a satisfactory safety environment (Aven & Pitblado, 1998). In combination with the legislative requirements, there can also be specific company requirements which necessitate an even higher level of safety in the design of an offshore installation.

4.3 Statistics of incidents in the offshore industry

The Petroleum Safety Authority (PSA) publishes yearly reports with incident statistics. Figure 7 below shows the number of incidents with ships on a collision course in relation to the number of installations with surveillance from StatoilHydro Traffic Control. The station provides surveillance services to 85% of all the offshore installations on the Norwegian Continental Shelf (Tor Egil Hopen Saue, 2008-11-03). As can be seen in the figure, the number of vessels on collision course with an installation seems to have a decreasing trend but a risk does however still exist.

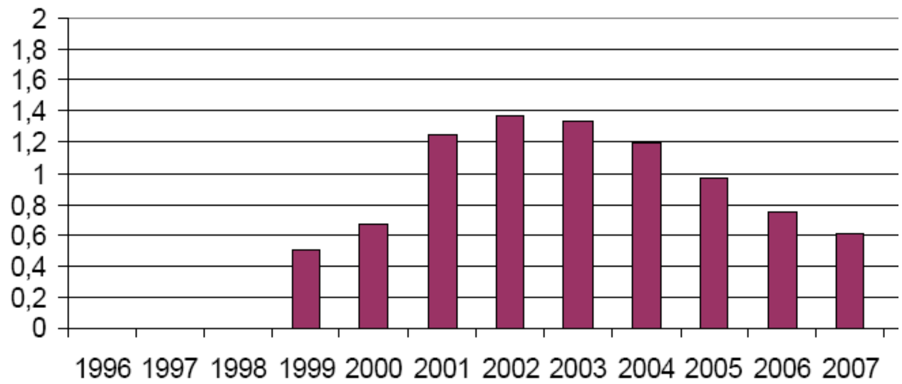


Figure 7: Number of ships on collision course in relation to the number of offshore installations with surveillance from Sandsli land based station (PSA, 2008a).

There have been 6 incidents worldwide during the time period 1980 to 2007 of such a severe consequence that the result became a total loss of the offshore installation (Vinnem, 2007). Out of these six, one incident occurred in the North Sea. Incidents of medium consequence are more common, even if this does not happen very often. In the time period between 2000 and 2007, three accidents have taken place in the North Sea (PSA, 2008a).

The reasons behind collisions vary widely but a common principle for all incidents seems to be a series of events that together contribute to the consequence collision. The Maritime Accident Investigation Branch (MAIB) summarise some of the most common reasons behind collisions as: over-reliance on equipment, inadequate training, poor navigational watch-keeping practices, shared watch-keeping, not good seamanship, inaction etc. (MAIB, 2008) A common conclusion within MAIB from accident investigations is that human error is the primary cause behind collisions (MAIB, 2004).

4.4 Uncertainties in accident data

There are quite a few different databases where incidents are reported; examples are the Marine Incident Database (Marine Accident Investigation Branch, UK), the Ship/platform collision incident database (Health and Safety Executive, UK) and the World Offshore Accident Databank (Det Norske Veritas). One of the major difficulties with comparisons of data and statistics from different databases is the divergence in definitions and concepts. There can be dissimilar understandings of what a human error means and the definitions are crucial when comparing data. There is no standardised accident reporting system in the maritime domain, which creates a problem when trying to find causal factors from accident data (Hetherington, 2006). Chapter 3of this thesis gives definitions of the concept human error and other essential explanations within the area. To be able to draw reliable and valid conclusions from investigations, they need to be based on the same (or at least transparent and comparable) assumptions and methods. It is also very difficult to compare incident statistics if methodologies and definitions are not described at all.

Another problem is the types of accidents that are reported. It is likely that no minor incidents are included in the statistics. It would be very useful if near-misses and small accidents were reported in accident statistics, to encourage a proactive concept in safety management rather than the frequent reactive measures that are taken subsequent to accidents.

As previously mentioned, a problem arises when using statistical data as the sole input to collision risks assessments, due to the low accident rates. Very few incidents have occurred and therefore the data can be questioned with regards to its reliability and whether conclusions can be derived from the limited experiences. A suitable method to somewhat get away from this problem is therefore to combine accident statistics with expert judgements and logical models.

5 Collision risk analysis

This chapter aims to give an overview of the models and methods that are used when assessing the risk for a ship collision. The focus is on the likelihood that a collision occurs and the models that deal with consequences are therefore not touched upon.

Several different risk analyses are completed when a new platform is built or modified. Risk analyses are undertaken for different events such as fires, leakages and collisions that can lead to loss of a main function, for example the control room, the evacuation possibility or the structural bearing capacity of the installation. As outlined in Section 1.3, this thesis is looking closer into the risk analysis for collisions. The result from the collision risk analysis will, together with the results from the other risk analyses, give a picture of the total risk for the offshore installation.

5.1 How to perform a maritime risk assessment

It is described by IMO that a generic model for collision risk shall not be viewed in isolation, but rather as a collection of systems, including organisational, management, operational, human, electronic and hardware aspects. The systems and functions should be broken down to an appropriate level and aspects of interaction of functions and systems. The extent of their variability should also be addressed. The human element is regarded as one of the most contributory aspects to the causation of accidents and must be incorporated in an assessment. Expert judgment is an important part of an assessment that provides proactive thoughts and ideas and is necessary where limited data exists. (IMO, 2007)

During an identification of possible hazards, it is necessary to combine both creative and analytical techniques with the aim to identify all relevant hazards. Structured group reviews with experts in the various appropriate aspects such as ship design, operations and management should be undertaken followed by a ranking of hazards and scenarios with regards to their contribution to an accident. (IMO, 2007)

5.2 Existing collision risk models

Most of the risk models for estimating collision frequencies are split into two steps. To begin with the potential collision risk is determined without considering any risk mitigation options, as rooted in an approach from 1974 (Friis-Hansen & Simonsen, 2002). The following step is then to assess the effects from aversive manoeuvres and how these reduce the risk for a collision.

Globally, there are a couple of different models that are used to assess the risk for collisions between vessels and offshore installations and a summary of the main models can be found in Table 1 below.

Model	Organisation
COLLIDE	Dovre Safetec
SOCRA	Maritime Research Institute
CRASH	Det Norske Veritas
COLWT	Germanisher Loyd
COLLRISK	Anatec UK Ltd
DYMITRI	British Maritime Technology Limited

Table 1: Overview of models that are used to assess ship collision risk (SSPA, 2008).

The models are in general pretty similar and the common approach is to estimate the number of possible collisions and multiply this with an estimated fraction of when a collision occurs. The causation factor considers the probability that a collision will not be detected and avoided. The models are based on the assumption that the collision frequency is proportional to the quantity of ships passing an offshore installation. This has however never been proved due to lack of data (DNV, 1998). The models COLLIDE and CRASH seem to be the models most frequently used within the Norwegian Continental Shelf and are therefore focused on throughout this chapter. Both of these models are mainly using theories from the Risk Assessment of Buoyancy Loss Project (RABL) from 1987 (DNV, 1998; Thomas Eriksen, 2008-11-04) and the models are therefore considered to be rather similar.

In COLLIDE and CRASH, the number of possible collisions is assessed by using information of shipping lanes in areas where the traffic is restricted to such, e.g. in the UK or by using historic shipping data as in e.g. Norway where there are no specified lanes. The traffic is usually considered to be Gaussian distributed as an attempt to include the vessels that happen to travel outside the shipping lanes or are not following the routes of the historical data. Historic shipping data can be found in AIS (Automatic Identification System) or in more simplistic data, of which AIS data is a more sophisticated and an increasingly common method.

5.2.1 Components in a collision risk analysis

Two conditions need to occur simultaneously for a collision to be a fact; a vessel on collision course and collision avoidance measures not successfully undertaken. The way of assessing the first component is described above. The second component is generally broken down into different parts (refer to Chapter 6):

1. Failure in planning or failure in executing the plan correctly.
2. Watch keeping failure (not adequate watch or radar failure in bad visibility).
3. Platform, stand-by vessel and land based surveillance stations must fail to alert the vessel.

The component *passage planning (1) is* regarded to depend on how long an installation has been in place and how effectively information about this has been distributed. The component is modelled in an event tree in COLLIDE. CRASH uses fixed plannability factors for different types of vessels and installation types and an empirical function dependent on time since the platform was installed. (DNV, 1998)

The element *watch keeping* (2) on the vessel varies slightly in CRASH and COLLIDE. The reasons behind a failure in watch keeping are identified in the RABL project as:

- No reaction by the watch-keeper of the bridge due to:
    - Absent from bridge
    - Present but absorbed
    - Present but incapacitated
    - Present but asleep from fatigue
    - Present but incapacitated from alcohol
    - Ineffective radar use (bad weather only)

(Technica, 1987)

Very limited statistical data on watch keeping failure exist and the component is therefore quantified by a combination of fault trees and expert judgements, where the probabilities of the detailed scenarios are at least partly based on judgements. The models separate the conditions in two scenarios, good or bad visibility, but this does only affect the probability for the reason "ineffective radar use". The remaining five failure modes have different values depending on type of ship (supply, standby and three different sizes of merchant ships). It is also assumed that the reason behind the failure has to last for a minimum of 20 minutes. The ranking of the reasons for a watch keeping failure, from highest to lowest probability, is: asleep, absent, absorbed, incapacitated from alcohol and incapacitated. The officer on watch being asleep is viewed as the significantly most important factor. The ranking just described is based on an average failure frequency for the merchant ships of three different sizes excluding supply and standby vessels. (Technica, 1987)

Platform initiated recovery (3) is considered to depend on the time available to perform any collision avoidance actions. This factor is taken to have a fixed value that is influenced by the organisation characteristics of the offshore installation.

5.2.2 Probability of a collision

The quantification of collision frequency is a simple multiplication of the individual components that are described above. The model used in CRASH is shown below and the model in COLLIDE is very similar:

$$F_{CP} = N \cdot F_d \cdot P_1 \cdot P_2 \cdot P_3$$

F_{CP} = frequency of powered passing vessels collisions.
N = total traffic in the lane.
F_d = proportion of vessels that are in the part of the lane directed towards the platform.
P_1 = probability that the passage planning stage is not carried out correctly.
P_2 = probability that the vessel suffers a watch keeping failure.
P_3 = probability that the platform or stand-by vessel fails to alert the ship in time to prevent a collision.

5.2.3 Vessel types

The models are generally broken up into being specific to the vessel type and analysed separately. Different models are therefore used to analyse the potential collisions of passing merchant vessel (i.e. cargo chips, cruise ships etc), fishing boats, offshore related traffic and navy traffic. As described in Section 1.5, this thesis does not consider the risk for collisions between offshore vessels and their dedicated offshore installations or submarines and installations. This leaves all other types of ships that may be present in the Norwegian Continental Shelf such as merchant vessels, cruise ships, fishing ships and supply boats (i.e. during the travel towards/away from other offshore installations).

5.2.4 Type of collision

Another distinction is a categorisation in collision scenarios; powered collision, drifting collision, collision on approach to an installation and collision alongside an offshore installation. The collision scenarios are related to the type of vessel and the first two collision scenarios are applicable to all vessel types, whereas the latter two only apply to offshore related traffic. This thesis is however mainly focused on powered collisions. A collision scenario is characterised as powered when the reason behind the incident is not considered as directly technical e.g. engine breakdown, which may develop into a drifting collision (refer to Section 7.1). This means that a powered collision can be caused by for example lack of situational awareness or failure in conducting collision avoidance measures.

5.3 Circumstances with an impact on collision risk

Several characteristics that are specific to an installation influence the risk for a ship collision. These circumstances must be taken into account when completing a collision risk analysis.

5.3.1 Characteristics of the installation

A large installation may be easier to identify, either visually or via radar, but the size also mean an increase of the area where a collision can happen.

Mobile installations are able to change location which can be a way to avoid a collision, but being mobile could also increase the risk for a collision if the new position is unknown to ships. Historical collision experience shows that the risk for a collision worldwide is 1.5 times higher for a mobile installation than for a fixed (DNV, 1998).

Collision avoidance measures can vary between installations. A type of warning systems is stand-by vessels (SBV's), but these are sometimes shared between installations and some are without. As mentioned in Section 4.3, StatoilHydro is supervising many of the offshore installations on the Norwegian Continental Shelf. Some of the others are either unguarded or are provided with surveillance from another station.

5.3.2 Location of an offshore installation

The location and hence the frequent shipping routes determine the traffic density surrounding an installation. A location near high traffic routes is considered to increase the risk for a collision (refer to Section 5.4). In addition to this, the weather conditions and how this influences the risk for a collision will vary with the location.

Accident statistics show that two out of three collisions occurred with installations that were isolated, i.e. far away from other installations (DNV, 1998). Although, when considering the positive effects of the StatoilHydro Traffic Centre and the warning the station provides, the risk for collision should presently not be significantly higher for an isolated installation (given that the installation is provided with surveillance).

5.3.3 Manned or unmanned installation

Without permanent personnel, recovery and warning of an approaching vessel via an SBV will not be initiated, as for a manned installation. The general activity around a manned installation will also increase the awareness and alertness of the watch keeper aboard a vessel (Vinnem, 2007). The risk posed to an unmanned installation could also be higher during night time, due to e.g. a failure with the power supply resulting in the installation being unlit and therefore not easy to localise for an approaching vessel.

5.3.4 Shipping traffic

There are no shipping lanes in the Norwegian waters, but there are areas where the traffic density is higher than in general. Ships that are regularly operating in the area are likely to have normal routes that are followed but there can be changes in these as well, due to e.g. severe weather conditions. (DNV, 1998)

5.4 Reflections

One of the weaknesses with the ship collision models described above lies within the component watch keeping failure, sometimes also referred to as ship initiated recovery. This component is based on the proceedings from a project (Technica, 1987) that was completed more than twenty years ago and many of the assumptions that were applicable then are not accurate today, with regards to the technology and management procedures. To exemplify, it can be mentioned how modelling of the navigation process was established prior to when technical equipment such as satellite based navigation systems and the use of AIS became common practice.

With regards to passage planning and navigational procedures, many vessels have been known to use installations as waypoints for navigation and references of locations. This has been a recognised hazard for a long time, considering that a direct course towards an installation followed by e.g. lack of attention can end up in a collision. This unsafe behaviour seems to have decreased due to preventive work such as information to seafarers (Tor Egil Hopen Saue, 2008-11-03).

6 The “as-planned” mode – a success scenario

This chapter presents the concept success scenario and how this is applied as a foundation when assessing ship collisions with offshore installations.

In this thesis, a success scenario is the basis for identifying failure scenarios that can lead to a collision, since these are considered to be deviations from the successful path. A success scenario can be described as the normal mode or the “as-planned” scenario (Kaplan, 1997). Before discussing success scenarios with regards to collision avoidance, it must be mentioned that the link between vessels and offshore installations is a complex system which includes several parameters and human and organisational involvement in many aspects. Many of the factors and components are also correlated and it is very difficult to present a simplistic model of the interface between vessels and offshore installations. Also, a success scenario is in this case not one single chain of events, rather several different chains that all share the same final consequence, i.e. that a collision does not occur.

6.1 On approach towards an offshore installation

Before a ship leaves port, an advance planning of the route is to be undertaken to facilitate travel in a safe and cost-effective manner. The planning should incorporate information on e.g. weather conditions and location of offshore installations. The procedure needs to consider updated maps and charts to identify all obstacles. There are a number of different ways for a vessel to become aware an offshore installation; directly visual by looking out from the bridge, by using e.g. ECDIS (Electronic Chart Display Information System), by using radar and by communication with other vessels, the installation or land based surveillance stations.

The proceedings can be considered as normal until the vessel is so close to the installation that it is seen as hazardous and at this point some sort of collision avoidance measure is usually undertaken. What is regarded as abnormally close differs between the perspective of a vessel and an installation, considering where the main ability of actions lies. The risk is hence likely to be perceived as significantly higher by people on the installation, when compared to people on the vessel (PSA, 2008a).

6.2 Defining “collision course”

Generally it can be said that a chain of events occur in a collision. Firstly, a vessel is on a collision course and secondly, the vessel does not change course away from the offshore installation. A ship on a straight course towards an installation is not necessarily a critical condition itself and actually a normal occurrence in the North Sea due to the high density of installations and ships. At some point and some distance, every ship is on a course towards an installation but this does however not necessarily lead to a collision.

There are different definitions of a collision course. The Petroleum Safety Authority (2008a) uses the following explanations:

1. When the course of a vessel is towards the safety zone of an installation and the installation has not been able to contact the vessel 25 minutes before a potential collision.
2. When the stand-by vessel has been mobilised to approach the incoming vessel this is regarded as a vessel on collision course, without respect to the time before a potential collision or the distance the vessel might pass the installation with.

The land based surveillance station in Sandsli operated by StatoilHydro generally works by the definition that a vessel is on collision course if it does not answer calls when it is 50 minutes away from the safety zone of an installation, with regards to course and speed (Tor Egil Hopen Saue, 2008-11-03).

6.3 Collision avoidance

The work procedure of the surveillance station with regards to time before an expected collision is as follows:

- 60-58 minutes – an alarm on the land based station is activated.
- 54 minutes – an attempt to contact the vessel via satellite phone, VHF, mobile phone and DSC (Digital Selective Calling).
- 50 minutes – if contact with the approaching vessel is not achieved, the offshore installation is notified.

Some offshore installations require more time for collision avoidance and evacuation procedures and the actions are therefore initiated 90 minutes before an expected collision. (Tor Egil Hopen Saue, 2008-11-03)

It is common that offshore installations in the North Sea have a radar collision warning system. The system automatically provides a warning if a vessel is on a course that passes close to the installation, which often is set to alert 45 minutes before contact (Vinnem, 2007). This enables the crew of the installation to identify a vessel on a collision course at an early stage, resulting in more time to carry out collision avoidance measures hence increasing the likelihood of performing these actions successfully.

On alarm, the SBV is given the course and position of the approaching vessel and starts moving towards it, while trying to contact the vessel on VHF. If there is no reply on the pursuit to radio contact, the SBV approaches the vessel and tries to notify by sounds, lights, pyrotechnics etc. This may be problematic due to the short time available, the relatively low speed of an SBV and difficulty in making contact with a vessel and especially those suffering a watch keeping failure. A possible action is that the SBV could try to deflect the course of the vessel by using physical contact, but considering how unsafe this action could be it is seen as rather unlikely.

The actions of the approaching vessel and the collision avoidance measures of the offshore installation are strongly correlated. The reason to why a situation occurs with a vessel on approach towards an installation is influencing how and if the actions taken by the installation are successful (Haugen, 1991). This can be exemplified by how e.g. a watch keeping failure on a vessel that is caused by the officer of watch being distracted is far more likely to be positively affected by collision avoidance measures than compared to if the officer is absent.

The probability of a collision is correlated to the distance to the ship and the risk level grows exponentially as per Figure 8 below. This due to how success of collision avoidance measures decreases with the distance.

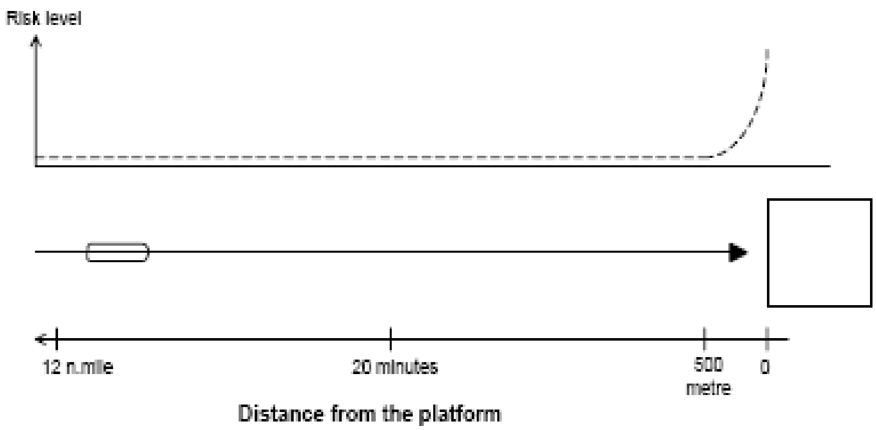


Figure 8: Description of how the level of risk is affected by the distance between a vessel and an offshore installation (Vinnem, 2007).

6.4 Reflection

A common principle in the link of actions described above is how there are several different levels where a failure can arise. More than one failure must take place at the same time for a collision to be a fact. A parallel can be drawn to Reason's Swiss Cheese Model (refer to Chapter 3) with several barriers between a hazard and a consequence and how an accident generally depends on a combination of events. Barriers in a collision scenario are e.g. watch-keeping on the ship and communication from the offshore installation as illustrated in Figure 9 below. The figure purely aims to provide a conceptual illustration of the chain of actions and can not be considered to be fully chronological or a full description of a collision scenario.

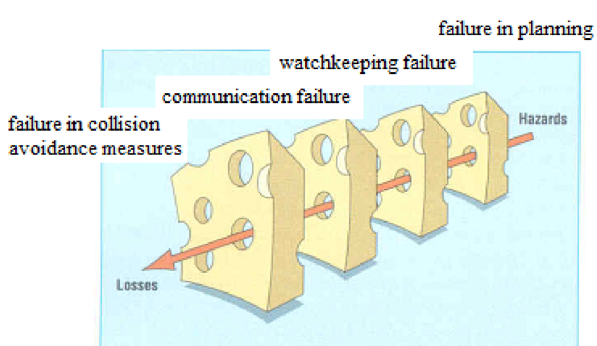


Figure 9: Illustration of different levels of failures that can cause a collision (Reason 2000, adopted by the authors of this thesis).

7 Identification of factors in collisions

This chapter presents the components in a collision scenario by using a structural model with scenarios, primary causes and underlying factors.

The purpose of the thesis is to identify all factors that may contribute to the risk for ship collisions and a new model was therefore developed. By this a new perspective is achieved, which may not have been possible if the models described in Chapter 5 were used. The identification and evaluation of factors was performed in several steps. Firstly, scenarios that can cause a collision were determined from literature reviews, accident statistics, risk analysis models and hazards identifications through workshops (refer to Section 2.2). Secondly, all factors that contribute to accidents were gathered and categorised in four scenario groups. The aim was both to assess factors that have been identified in earlier studies and try to find new factors that contribute to the collision risk.

External influences such as the surrounding society and legislation were not taken into account when identifying factors, only elements within the organisation of a ship were considered when discussing the risk for a collision.

The factors are divided into primary causes and underlying factors. Primary causes are actions that directly lead to a scenario and are dependent upon underlying factors. The scenarios and primary causes can be seen as active failures, while the underlying factors can be compared to latent condition (refer to Section 3.2). The underlying factors for a specific primary cause will not be regarded as contributing to the collision risk if the primary cause is not important for the scenario. In the same way will the primary cause be seen as less important if its overlying scenario is not contributing to the collision risk.

It is sometimes appropriate to explain a scenario by both primary causes and underlying factors. Other scenarios are complicated to describe in specific primary causes and are therefore directly outlined by underlying factors, due to the large amount of possible events and hence a difficulty to categorise these.

As seen in Figure 10, scenarios, causes and factors that may cause a collision are structured in a hierarchical model created by the authors of this thesis, with four levels where collision is the top event.

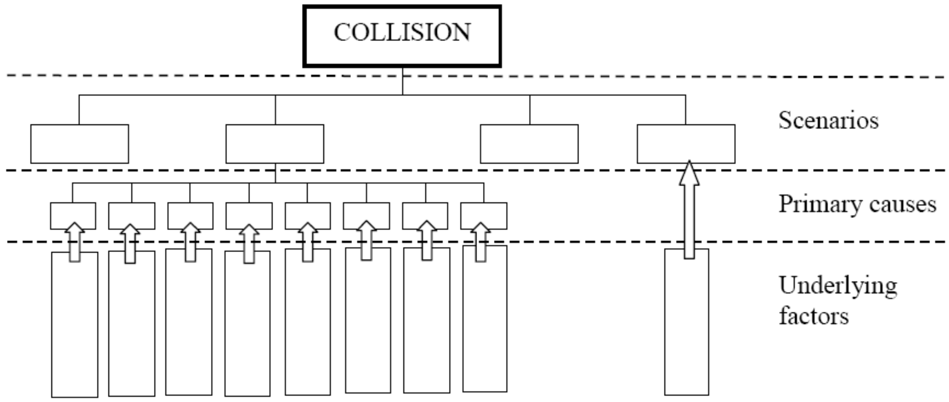


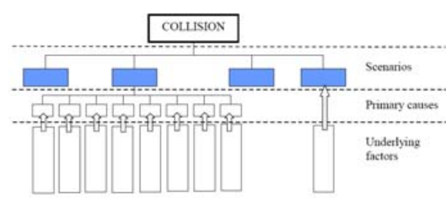
Figure 10: A hierarchical model that shows the connection between a collision and the scenarios, primary causes and underlying factors.

The underlying factors are presented separately within this thesis and categorised into groups as in most other research projects, e.g. a group of organisational factors. The factors may be more or less correlated with each other, which makes it challenging to fully separate them into categories (refer to Section 3.3). By referring to the definitions of each factor (refer to Appendix D) and always keeping them in mind when reading this thesis, there will hopefully not be any major difficulties in understanding the factors and their context.

A summary of all introduced scenarios, primary causes and underlying factors can be found last in this chapter (Figure 12, p.41).

7.1 Four scenarios contributing to the collision risk

The overlying categorisation in four scenarios represents the first level below the outcome collision and can be described as groups of reasons to why collisions occur, where all scenarios contribute to the collision risk.



They can separately be the primary reason for a collision but can also occur during the same chain of events that lead to an accident.

Four scenarios are identified and assessed in this thesis:

- Intentional failure
- Technical problems
- Lack of awareness
- Handling error

Intentional failure is a situation when somebody on a ship aims to collide with an installation, e.g. an act of terror, which means that the scenario not can be classified as an accident. Intentional failure is very seldom mentioned in literature and no collisions with offshore installations have ever been reported due to this type of actions. There is a lot of secrecy within organisations about threats and emergency preparedness.

Technical problems involve failures with steering equipment, machinery etc. that may hinder a ship from changing course away from an installation. The officer on watch is in this scenario aware of the collision course and the potential danger but can not do anything about it. If this scenario would result in a collision it could be compared to the concept "drifting collision" (refer to Section 5.2.4). Data about this kind of failures can be found in accident reports or technical equipment reliability data (refer to Section 7.1.2) and it is often rather clear if the primary reason for an accident is a technical problem.

Lack of awareness is described as when the officer on the bridge for some reason is not aware of the offshore installation, the collision course or the position of the ship itself. This means that no actions to avoid a collision are undertaken on the ship. Lack of awareness includes for example that the officer on watch is distracted or asleep. This scenario is a well known problem amongst people working within the maritime sector and is often referred to in literature and accident reports, even if other concepts sometimes are used.

Handling error arises from a situation where the officer on watch is aware of an offshore installation but for some reason fails to avoid collision. This means that the officer on watch possesses situational awareness, but there is a failure when undertaking collision avoidance measures. An example can be if a ship is changing course away from an installation but not enough to avoid an accident. The concept handling error does not seem to be discussed when assessing the collision risk, but failures that can belong to this category are however mentioned in accident reports. The scenario has also been discussed and supported during workshops.

7.1.1 Interaction between scenarios

As already mentioned, the causes behind each scenario can be influenced by different underlying factors. A technical problem could for example depend on insufficient maintenance which may be classified as an organisational factor. The scenarios can also be correlated with each other. One scenario can initiate a situation whereas another scenario is the primary reason for the collision. For example can a technical failure, such as a black out, lead to an awareness failure which then is the primary reason for the collision.

As discussed in Chapter 5.2.1 where the collision risk models are described, the outcome of a scenario is not only dependent on the actions of a ship. Handling error and lack of awareness can be prevented through external communication from land based stations and/or the offshore installation. External communication will probably not affect an intentional failure or technical problem.

7.1.2 Selection of scenarios to assess

In the next sections the scenarios lack of awareness and handling error are further evaluated. The thesis is not looking closer into intentional failures because of the assumed negligible likelihood, the difficulties with confidentiality and problems with effective preventive measures as previously mentioned.

Technical problems tend to be a reappearing cause to collisions and maritime accidents, but its contribution varies between different sources. Information from some statistical documents is summarised below to give context to how often technical problems contribute to maritime accidents:

- 4% of all near misses between ships and platforms were related to steering failure and 20% of all near misses between ships and platforms in UK waters were related to engine failure (HSE, 2003)
- 5% of all collisions in Canadian waters (Baker & McCafferty, 2005)
- 5% of all collisions in UK waters (Baker & McCafferty, 2005)
- 6% of all collisions in Australian waters (Baker & McCafferty, 2005)

In view of the previous brief discussion, a decision to not further assess direct technical problems is made because of how there exists more data and statistics within the area of technical reliability than when compared to human reliability data.

Awareness failure and handling error seem to be more complex and involve human and organisational factors that are not easy to find data or statistics about. These type of failures are also quite vaguely described in the existing models for collision risk analysis, why it is important to evaluate them further.

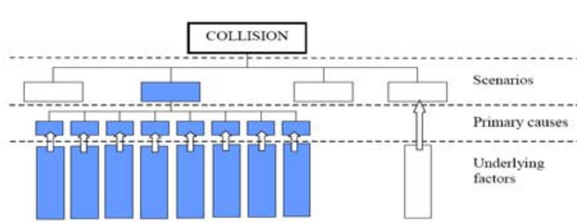
7.2 Lack of awareness

A lack of awareness may result in an accident, depending on when (or if) awareness is achieved again. The longer the distance is between the vessel and the offshore installation, the more likely it is that the officer on watch regains awareness before a collision take place. A few minutes of unawareness will probably not result in a collision. In this thesis, lack of awareness that can result in a collision is considered and therefore incorporates duration to some extent. A comparison can be made to the RABL project where it is taken into account that a watch keeping failure must last for 20 minutes to cause an accident (Technica, 1987).

Eight primary causes behind the condition lack of awareness have been acknowledged in this thesis. The scenario watch keeping failure, which is used in the collision risk models today (e.g. CRASH), mainly consists of the same kind of failures that are adopted in this thesis as primary causes.

7.2.1 Primary causes

The primary causes that are identified to lie behind lack of awareness are illustrated in Figure 11 below, followed by explanations of the causes. Several sources recognise the primary causes below as reasons to why a lack of awareness occur (e.g. HSE, 1999; Technica, 1987). There are though some differences within the concept lack of awareness between the two sources of literature. Information from the documents has been used as a basis together



with reflections from the authors of the thesis of what is considered to affect the likelihood for the scenario lack of awareness. Additions to the existing theories are:

- Failure related to navigational equipment
- External communication

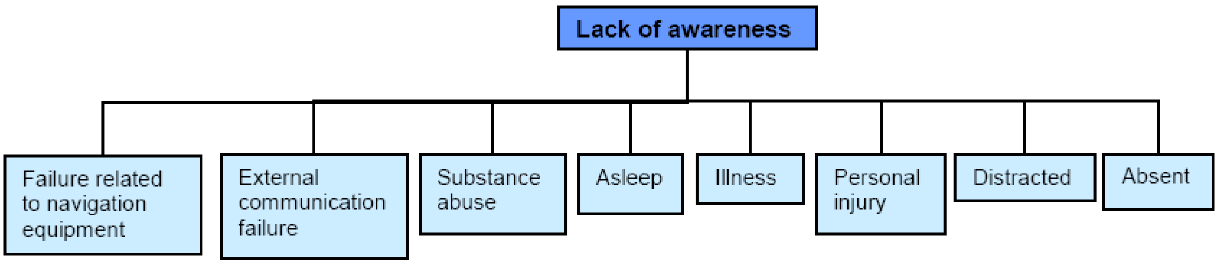


Figure 11: The scenario lack of awareness and the primary causes behind this scenario.

A *failure related to navigational equipment* includes everything regarding the navigation process. Therefore failures when using the equipment, actual technical malfunctions and lacking devices etc. are considered.

An *external communication failure* is related to problems with the technical communication system, an error in receiving or interpreting information and lack of communication. This situation is therefore considered to be a two-way communication, where the failure occurs at the ship. This primary cause does only consider incoming communication from other vessels, installations or land based stations and not the communication that occurs internally on the vessel.

Lack of awareness due to *substance abuse* considers if the officer on watch is present on the bridge but under the influence of some sort of substance such as alcohol, drugs or medication, which decreases the capabilities of the person.

Another reason to why an officer on watch lacks awareness of a situation may be due to the person being *asleep* on the bridge.

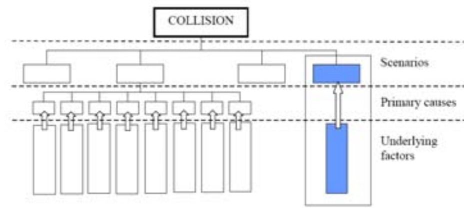
A sudden *illness* of the person being responsible of watch keeping can result in a lack of awareness. This can be linked to for example a heart attack, a stroke or an epileptic attack.

Another primary cause is identified to be if a *personal injury* occurs to the officer on watch that prevents the person from being fully aware of the situation. This category includes personal injuries for instance falls, head injuries etc.

Distraction can originate in the officer on watch performing other tasks simultaneously with watch keeping such as paper work and phone calls or that many people are present on the bridge.

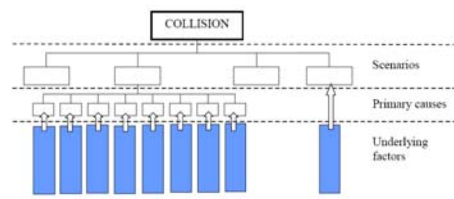
If the watch keeper is *absent* from the bridge during the watch, this inevitably results in lack of awareness.

7.3 Handling error



Handling error is not discussed in the models for ship collision analysis (DNV, 1998; Technica, 1987). In this thesis the concept is adopted and a handling error is directly broken down into underlying factors, in contrary to the scenario lack of awareness which first is divided into primary causes. This is because of the many different kinds of handling errors that can be identified and the problem to categorise these. If a handling error does occur, it is very likely to result in an accident. If the installation is identified at a late stage this also influences the execution and success of the actions to avoid a collision.

7.4 Underlying factors



An overview of the interactions between underlying factors and primary causes are visualised in Figure 12. Presented below are all the underlying factors that are identified to contribute to the collision risk, to one extent or another. The factors are sorted alphabetically within each group, not in relation to the contribution of the factor. Many of the underlying factors are considered to play a role in more than one scenario, whereas some of the factors are more likely to be specific to one scenario.

Equipment related factors
Blackout
Failure related to navigation equipment
Inadequate technical equipment
Maintenance
Technical failure of communication equipment
Technical failure of navigation equipment

External factors
Duration of journey
Extreme event on ship
Level of other vessel activity
Time of day
Weather

Factors related to handling
Familiarisation with ship characteristics
Failure to ensure fitness at handover
Lack of communication
Misunderstanding
Not following guidance
Not using independent reference equipment
Over reliance on technical equipment
Personal stress
Wishful thinking

Organisational factors
Bridge procedures
Health management/culture within the organisation
Layout of the bridge
Organisational culture
Reporting and follow up
Time into the watch
Type of watch system
Workload too high
Workload too low
Work pressure

Personal characteristics
Age and general health
Competence
Fatigue
Language
Perception of negative effects from substances

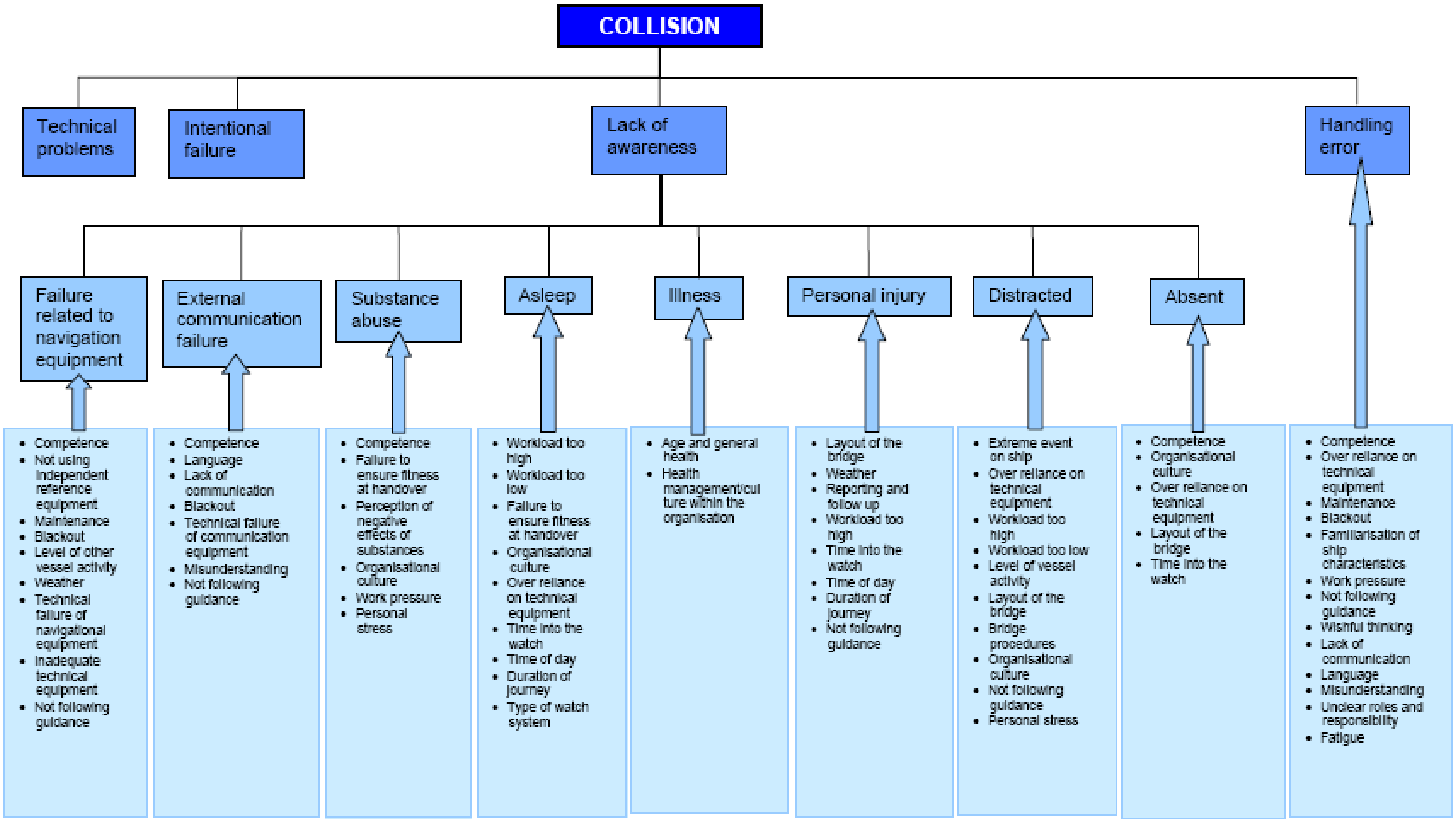


Figure 12: An illustration of how the identified scenarios, causes and factors are linked.

8 Evaluation of factors in collisions

This chapter presents the analysis of the thesis, which includes the results from interviews and workshops combined with statistics from literature.

By combining results from expert judgements with accident statistics and research, a solid background to understanding the reasons behind collisions should be achieved. The presentation of results also includes reflections from the authors of this thesis.

Interviews were undertaken to look further into the primary causes and the underlying factors. A ranking of the factors was made in the study which included a possibility to add other factors. The interviews were performed as open dialogues with an interview guide as a basis (found in Appendix A). This gave an opportunity to freely discuss everything brought to mind, to define concepts and explain uncertainties with quantitative comparable results as an outcome.

8.1 Interviews

Expert judgements were gathered via interviews with 19 people with experience from e.g. sea faring, collision risk analysis and maritime human factors research. A full list of respondents is found in Appendix B. Due to the time available for this thesis and the amount of coordination and travel necessary to carry out the interviews, it would not have been possible to add more participants to the study. The interviews lasted 1-1.5 hours and was always performed by both authors of this thesis. Of the 19 interviews, 5 were completed over telephone and the remaining 14 in person. The respondents were handed the interview guide together with a list of definitions a couple of days before the interview.

The questions were all laid out in a similar manner, by inquiring the contribution of each scenario/primary cause/underlying factor with regards to the overlying concept; i.e. the level above in the structural model. An example of a question is given below:

> *" Considering collisions between ships and offshore installations, to what extent do you think the following scenarios contribute?*
>
> *a) Technical failure*
> *b) Lack of awareness on ship*
> *c) Handling error in collision avoidance*
> *d) Intentional failure*
> *e) Other, please specify"*

A five step scale was used to make sure that some divergence between the results could be achieved, which would not have been likely if a three step scale was used. Also, providing too many options (e.g. a scale with ten levels) could have created dilemmas in what answer to choose.

All scenarios, causes and factors were defined, either in the questionnaire itself or in a document with all concepts that were adopted in the interviews (refer to Appendix D). As can be seen in the question above, there was a possibility to add other factors which several of the respondents took the opportunity to do and these factors are also briefly discussed in the following sections.

8.2 Method for assessing the results

This chapter follows the hierarchical structure from Chapter 7 and therefore begins with the scenarios, followed by primary causes and underlying factors.

It should be noted that the answers from the interviews are quite often wide spread and that it therefore can be difficult to draw general conclusions. The results from the interviews, i.e. the answers illustrated in a diagram, are found in appendix E and F. It is important to look at the diagrams presented for each factor to fully understand the opinions of the interview participants. The purpose of the diagrams is to visualise the answers and consequently provide transparency to the assessment process. The results from the interviews can not be seen as "statistical truth" that can be assessed by means, averages etc. due to how the sample size would be invalid for this type of assessment. Instead, tendencies and trends in the contribution of each factor are identified. The results from the interviews are presented in diagrams with the number of respondents on the y-axis and the distribution of the answers, i.e. the contribution of each scenario/primary cause/underlying factor, on the x-axis.

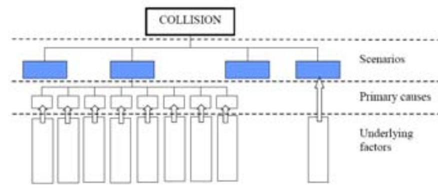
The results from the interviews showed that a majority of the underlying factors had rather clear tendencies with regards to their contribution, while some had more of a divergence and are therefore problematic to draw conclusions from. The latter are categorised as vague factors and must not be regarded as less important than the factors where more apparent tendencies are found. The underlying factors may be very important and significantly contribute to the collision risk or they can be the opposite, i.e. not have any contribution at all, but this thesis has however not been able to show these indications. Additional studies need to be made to come to any conclusions of the impact of the vague factors.

Only a small selection of the literature is referred to in the evaluation, due to how much information that was found. Information about the primary causes is integrated in the following section whereas statistics concerning the underlying factors is presented in Appendix F in relation to each diagram.

Factors added by the experts during interviews that can not be related to the initial scenarios or causes can be found last in this section. The added factors are not included in the graphical presentations of the results.

A few respondents did not answer all the questions. There are three answers missing, resulting in three questions having 18 answers instead of 19. Because of the way the results were interpreted, this should not adversely affect the conclusions.

8.3 Scenarios



The first question in the interviews concerned to what extent the four different scenarios technical problem, lack of awareness on ship, handling error in collision avoidance and intentional failure are contributing to the risk for a collision between a ship and an offshore installation. The purpose behind this question was mainly to validate the previously made assumption, namely that the scenarios lack of awareness and handling error were chosen to focus on.

The most contributing scenario to the collision risk seems to be lack of awareness, which 14 respondents regard as having significant or very significant contribution. Technical problem and handling error are assessed to have little or medium contribution by most respondents. There are also some higher rankings for technical problems and both higher and lower rankings for handling errors. The respondents perceived intentional failure as a very unlikely contributor to the risk for collisions, 16 out of 19 have answered no contribution and the other 3 answered little contribution. The results are shown in Figure 13. It was also mentioned that lack of awareness is not as common as it has been because of higher safety requirements today (Helge Samuelsen, 2008-11-04). Several respondents pointed out that there should not be any problems to change course and avoid a collision with an installation, which makes handling error rather unlikely.

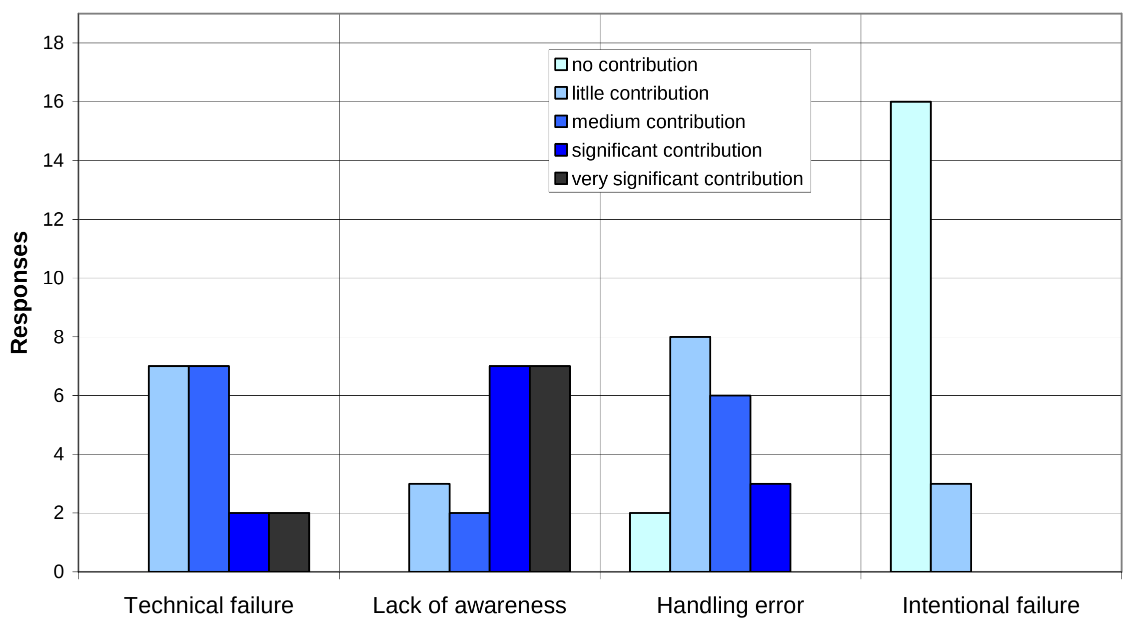
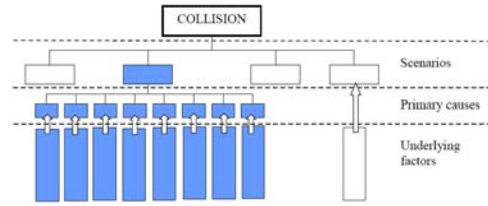


Figure 13: Diagram showing to what extent the scenarios contribute to the risk for a collision.

8.4 Lack of awareness

Question 2 of the interviews considered the primary causes to lack of awareness, i.e. failure related to navigational equipment, external communication failure, distraction, absence from bridge and incapacitation due to substance abuse, sleep or illness.



The eight primary causes that have been identified in Section 7.2.1 and their contribution to lack of awareness are presented in Figure 14 below and further in Sections 8.4.1 to 8.4.8.

Added primary causes

Some respondents implied that unclear roles and responsibilities can be a contributing factor to awareness failure. The internal communication on the bridge and indistinct roles may create misunderstandings about who is in command. This could result in that no one takes responsibility for navigation and therefore unawareness.

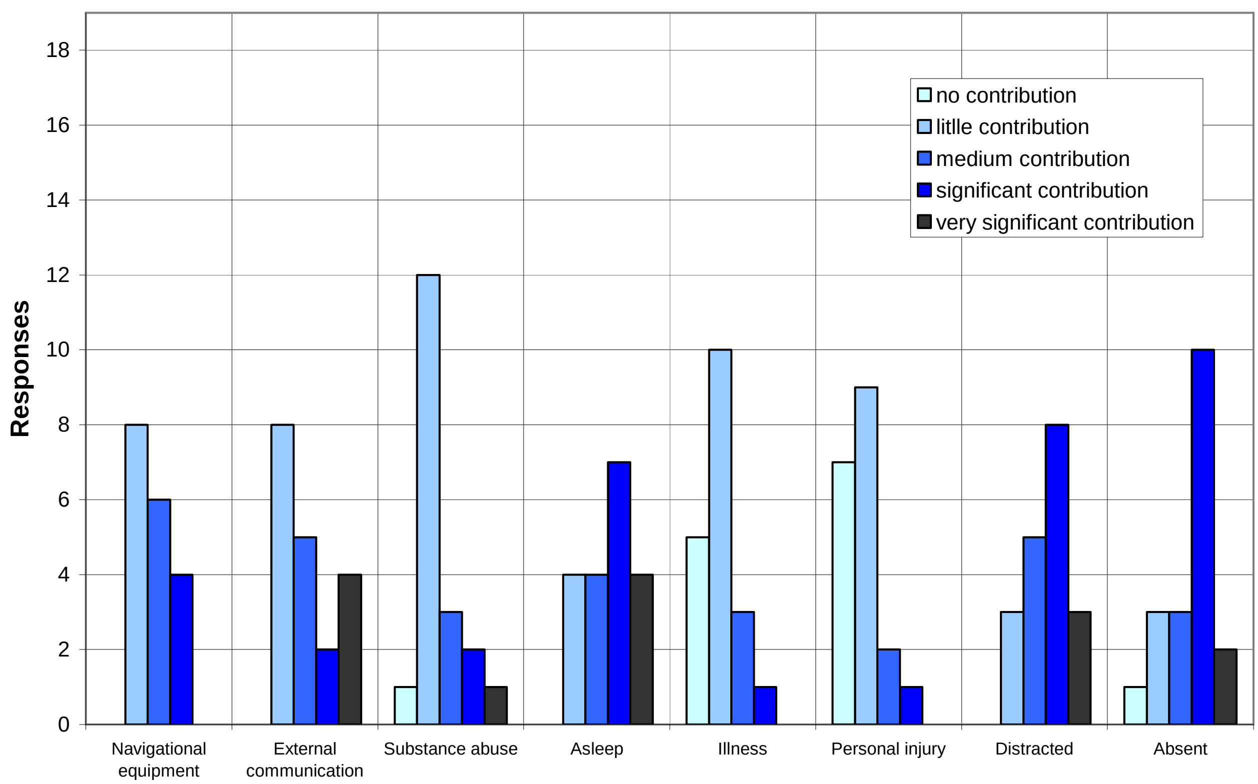


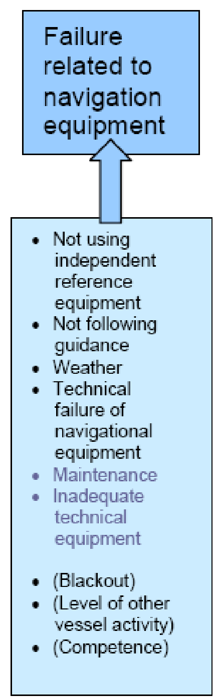
Figure 14: Diagram showing to what extent the respondents considered the primary causes contribute to the scenario lack of awareness.

A summary of the underlying factors and their impact is presented in relation to each primary cause. Beside each section is a figure that shows the primary cause and the underlying factors. If a primary cause or an underlying factor is shaded the factor is seen as less important. The underlying factors that did not show any clear tendencies are shown in brackets. The underlying factors are sorted with regards to their importance.

8.4.1 Failure related to navigation equipment/process

The answers from the interviews are spread from little to significant contribution with a tendency towards little contribution. Failures related to navigation equipment/process are not mentioned very often in accident reports or other literature. In a study of incident data from 1991-2001, navigation was determined to cause approximately 8 % of all accidents (Baker & Seah, 2005). By regarding the results, the navigation process could have some contribution to a collision scenario. However, for this primary cause to result in a collision it is likely that other barriers need to fail. These barriers can for example be a failure to keep a proper look-out through the window, no warning from the traffic surveillance station or the installation, a failure in receiving communication etc. All in all, a navigation failure is hence not considered to have a significant impact on the collision risk.

Underlying factors	Results from interviews	Results from literature studies
Not using independent reference equipment	Significant contribution	No specific data
Not following guidance	Medium to significant contribution	May be a contribution
Weather	Around medium contribution	Unclear tendencies
Technical failure of navigational equipment	Average contribution but may be not likely due to redundancy	Medium contribution
Maintenance	Little or medium contribution	Small contribution
Inadequate technical equipment	Small to medium contribution	Few references, small contribution



Vague trends
Blackout, level of other vessel activity, competence
Summary of important factors
Not using independent reference equipment, not following guidance, weather conditions and technical failure of the navigation equipment.

Added factors

-

8.4.2 *External communication failure*

The opinions concerning to what extent external communication is a primary cause to the scenario lack of awareness are divided between the respondents and it is difficult to say anything general about it. A majority mean that its contribution is little or medium but there are also several rankings as very significant. Many respondents claimed that the importance of external communication may be more substantial when discussing collisions between two ships than in a situation with a ship and an offshore installation, which also is reflected in the literature.

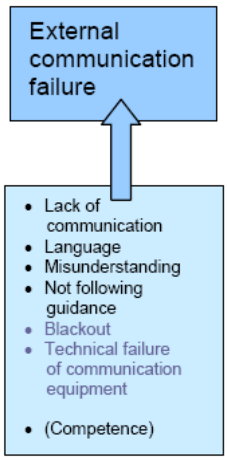
Grech et al. (2008) note that verbal communication can be difficult in noisy environments and that it also can be problematic when using technical communication devices with poor sound quality. In a breakdown of communication related accidents 22.4 % were due to language problems, 18.4 % were due to technical problems and 59.2% were considered "problematic" communications. (McCafferty & McSweeney, 2003)

The discrepancy with regards to how important external communication is perceived among respondents and also when compared to literature, resulted in that the contribution of the factor can not be validly evaluated. Even if it was difficult to outline the significance of communication failures in collisions between vessels and installations, the underlying factors to errors in communication have been possible to summarise.

Underlying factors	Results from interviews	Results from literature studies
Lack of communication	Significant contribution	Medium
Language	Equal distribution, strong tendency towards significant	Significant
Misunderstanding	Equal distribution, tendency against significant	No data
Not following guidance	Medium or significant contribution	Medium contribution
Blackout	Not an important contribution	Low
Technical failure of communication equipment	Low contribution	Medium

Vague trends
Competence

Summary of important factors
Lack of communication, language, misunderstanding and not following guidance.



Added factors

Information overload was also seen as a causal factor to external communication failure. When listening to the VHF radio in areas with high traffic density, there can be people talking almost constantly and this would make it very difficult to recognise vital communication.

8.4.3 Substance abuse

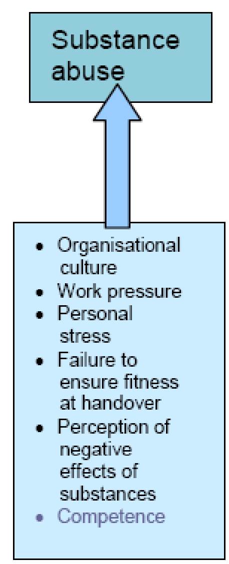
A majority of the respondents rank substance abuse as having little contribution to lack of awareness and one person answers no contribution. Although, three persons view the contribution to the collision risk as significant or very significant.

Lang (2000) writes that there is very little recent evidence of humans failing at sea due to alcohol and that alcohol as primary cause to human failure has largely disappeared, mainly due to very strict rules onboard many ships. This opinion is confirmed by Grech et al. (2008) who ascribe this diminish the greater knowledge about the effects of alcohol, more widespread testing and alcohol policies. It was also confirmed by some of the respondents who described alcohol use as a decreasing problem. There are though other substances than alcohol, two respondents specifically mentioned drugs and medicine abuse (Jens-Uwe Schrøder, 2008-11-13; Stefan Lindberg, 2008-11-14). These are problems that are seldom mentioned in literature but Lang (2000) mean that there is circumstantial evidence to indicate that drugs play a part in some accidents.

Taking into account the discussion above, it is regarded that an awareness failure is unlikely to be caused by an officer on watch being incapacitated due to substance abuse. If on the other hand this primary cause would take place, the underlying factors seen as contributory are as follows:

Underlying factors	Results from interviews	Results from literature studies
Organisational culture	Significant contribution	Significant contribution
Work pressure	Significant	Small-medium
Personal stress	Significant contribution	Medium contribution
Failure to ensure fitness at handover	Medium to significant	Small-medium
Perception of negative effects of substances	Medium to significant	No data
Competence	Low contribution	No data
Vague trends -		

Summary of important factors
Organisational culture, work pressure and personal stress, failure to ensure fitness at handover and perception of negative effects of substances



Added factors

Participants mentioned that the working environment/teamwork onboard a ship, medication and addiction might play a part in an officer on watch being incapacitated by substance abuse. It can be agreed on that the working environment could be a influential factor to why a person is using substances and that this perhaps is not included in either of the factors organisational culture, personal stress or high workload. Problems with medication and addiction would hopefully be picked up during medical checkups, tests or identified otherwise.

8.4.4 *Asleep*

The answers from the interviews are almost evenly distributed between little, medium, significant and very significant contribution but with a small peak at significant contribution. It was mentioned in an interview that the officer on watch being asleep is likely to be more common at ships with crew of minimum levels (Carl-Henric Wulff, 2008-11-10). Sleep as a causation factor is probably underestimated in accident reports because of difficulties in measuring (Swedish maritime administration, 2008). Indicators of fatigue are often difficult or impossible to identify following an accident (Grech et al, 2008). In an anonymous study with Swedish seafarers, 73% admitted having fallen asleep once or several times during their watch (Lützhøft & Kiviloog, 2003). With regards to the findings, sleep is viewed as an essential reason to why collisions happen.

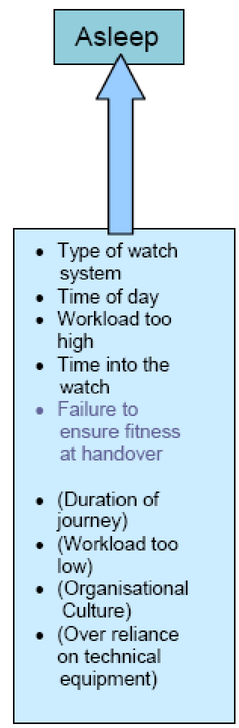
Underlying factor	**Results from interviews**	**Results from literature studies**
Type of watch system	Significant to very significant	Significant
Time of day	Significant contribution	Significant
Workload too high	Medium to very significant contribution	Medium
Time into the watch	medium to significant	Medium
Failure to ensure fitness at handover	Small contribution	No data

Vague trends

Workload too low, organisational culture, duration of journey and over reliance on technical equipment.

Summary of important factors

Type of watch system, time of day, workload too high and time into the watch.



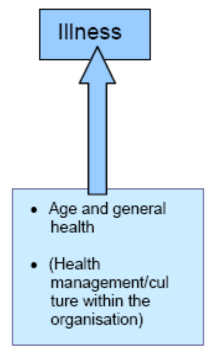
8.4.5 *Illness*

An illness is generally perceived by the respondents as a small contributor to the scenario lack of awareness. Almost 85 % have answered no or little contribution. It was mentioned that there are quite strict rules for medical check-ups at sea which should result in a good health standard. The literature partly gives a different view. Cases of more severe diseases on ships are fewer today than previously but ships are still environments where minor illnesses can be passed on easily. Often the consequences are relatively small, but it would still have an impact on task performance (Grech et al, 2008). Research shows a large risk for the short and long term health of those working in shift systems (Lützhöft et al, 2007). Lack of awareness due to an illness which later could cause a collision is however seen as a scenario with very limited influence, when keeping e.g. the rigorous health management procedures and the small likelihood for a severe illness in mind.

Underlying factor	Results from interviews	Results from literature studies
Age and general health	Medium to very significant contribution.	No data

Vague trends
Health management/culture within organisation

Summary of important factors
Age and general health.



Added factors

Seasickness and inflexible systems are mentioned as underlying factors to unawareness due to illness. There is also a dilemma with the inflexible systems onboard ships, which often are without redundancy if a person gets ill.

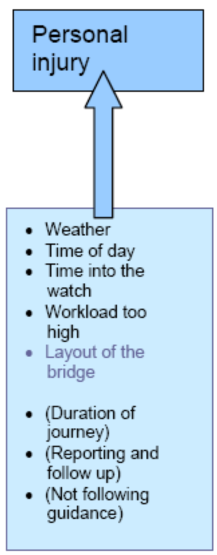
8.4.6 Personal injury

An accident that causes a personal injury is ranked as a factor with low contribution to lack of awareness by almost all respondents. Some of the commentaries during interviews were how unlikely this is and that the bridge is a rather safe environment. No specific information has been found where the officer on watch has been incapacitated due to a personal injury, but injuries are mentioned in relation to work at deck. One of the experts participating in an interview mentioned an experience with an officer on watch falling at the bridge and breaking his neck which yet shows that it could happen. Although, a personal injury on the bridge that results in lack of awareness is considered to have almost negligible impact on the risk for a collision. When assessing the underlying factors to a personal injury, the weather condition is ranked as the most important factor followed by time of day, whereas the layout of the bridge is not significant.

Underlying factor	Results from interviews	Results from literature studies
Weather	Significant contributor	No data
Time of day	Medium to significant	No data
Time into the watch	Small to medium contribution	Small contribution
Workload too high	Around medium contribution	Small contribution
Layout of the bridge	Small	Small

Vague trends
Duration of journey, reporting and follow up and not following guidance.

Summary of important factors
Weather, time of day, time into the watch, workload too high.



Added factors

When discussing the factor report and follow up of accidents and near-misses during the interviews and its impact on personal injuries, not many respondents understood the factor. Following an explanation, some of the respondents recognised the contribution, but the factor seems to be better known within the risk management area than in general.

Another point of view was that the organisational culture has an impact on the primary cause personal injury. This might be a contributory factor, but compared to other factors such as heavy weather and time of day, the organisation culture does probably not have a significant impact on injuries.

8.4.7 *Distracted*

The results from the expert judgment show that distraction has a contribution that is spread between little and significant contribution, with a majority leaning towards a significant influence. Distraction or inattention is regarded as a problem in several research projects, but no projects that search deeper into the problem have been found. A review of accidents in Canadian waters 1981-1992 establishes that 20 out of 273 accidents were related to distraction (7%). In a research project about safety measures inattention is perceived to cause 14 % of all situations where the officer on watch lost the navigational control (Kristiansen & Soma, 1999).

An example mentioned during interviews was how the officer on watch can be working with other tasks and simply forgets about the instruments and to look out (Petter Øverås, 2008 -11-04). Another example is alarms connected to the bridge which can draw attention away from watch keeping (David Wendel, 2008-11-07; Tor Egil Hopen Saue, 2008-11-03). With regards to the results from the interviews, remarks and findings in literature, the situation of an officer on watch being distracted is considered to play a significant role in a lack of awareness scenario.

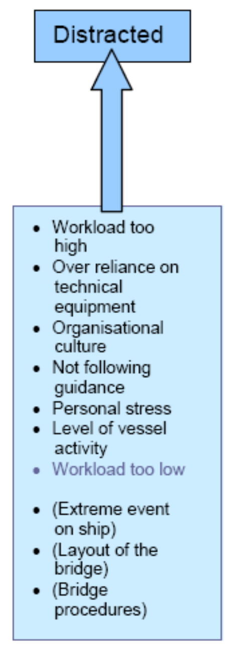
Underlying factor	Result from interviews	Result from literature studies
Workload too high	Medium to significant contribution	Significant contribution
Over reliance on technical equipment	Medium to significant contribution	Significant contribution
Organisational culture	Medium to significant contribution	Significant contribution
Not following guidance	Medium contribution	May have a contribution
Personal stress	Significant contribution	Significant contribution
Level of other vessel activity	Medium contribution	Little contribution
Work too low	Little to medium contribution	No specific data

Vague trends

Extreme event on the ship, layout of the bridge and bridge procedures

Summary of important factors

High workload, over reliance on technical equipment, organisational culture, not following guidance, personal stress, level of other vessel activity



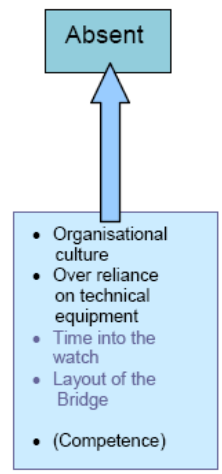
Added factors

Three additional underlying factors were considered to have an impact on an officer on watch being distracted; non navigational related communication, e.g. with people on the bridge, onboard activities on smaller ships, such as fishing, and conversations on the radio. All of these three factors are acknowledged as important to why distraction takes place.

8.4.8 Absent

According to the respondents, absence can be considered as a major problem when discussing lack of awareness. 12 participants regard the contribution of the factor as significant or very significant, while 7 mean that the impact is medium or lower. Many respondents mentioned that “absence should just not happen”. Accident reports from the Swedish maritime administration shows that it can happen (Swedish Maritime Administration, 2008), even though it is only mentioned as a contributing factor in one of 139 accident reports. In a research report, 3 % of the situations where the officer on watch loose the navigational control may be caused by the officer being absent (Kristiansen & Soma, 1999). An absent watch keeper is seen as having significant involvement in the scenario lack of awareness, mainly due to the results of the interviews but also considering discussions in literature (e.g. HSE, 1999).

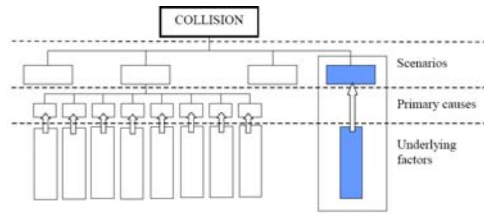
Underlying factors	Results from interviews	Result from literature studies
Organisational culture	Very significant contribution	Significant contribution
Over reliance on technical equipment	Medium to significant contribution	Significant contribution
Time into the watch	Little contribution	No specific data
Layout of the bridge	Little contribution	No specific data
Vague trends		
Competence		
Summary of important factors		
Organisational culture and over reliance on technical equipment.		



Added factors

Having onboard activities was also regarded to impact on an officer on watch being absent from the bridge.

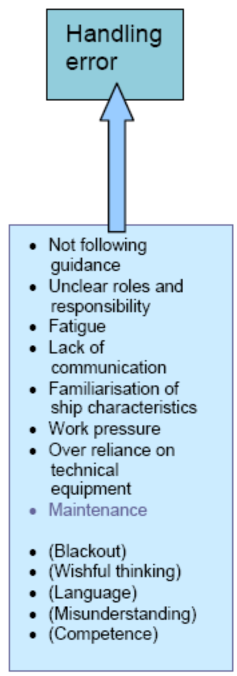
8.5 Handling error



As previously described in Section 7.3, the scenario handling error is directly connected to underlying factors and not first divided into primary causes.

The scenario handling error and its contribution to the collision risk was described in Section 8.3.

Underlying factors	**Result from interviews**	**Results from literature studies**
Not following guidance	Medium to significant contribution	Average contribution
Unclear roles and responsibility	Medium to significant contribution	No specific data
Fatigue	Medium to very significant contribution	Average contribution
Lack of communication	Average contribution	Average contribution
Familiarisation of ship characteristics	Medium to significant contribution	Little contribution
Work pressure	Significant contribution	Significant contribution
Over reliance on technical equipment	Medium to significant contribution	Significant contribution
Maintenance	Little to medium contribution	Little contribution



Vague trends
Blackout, wishful thinking, language, misunderstanding, competence
Summary of important factors
Not following guidance, unclear roles and responsibility, fatigue, lack of communication, familiarisation with ship characteristics, over reliance on technical equipment.

Added factors

-

8.6 Factors added during the interviews

In addition to the factors identified by the authors, the respondents had the possibility to add other factors in each question. Most of the added factors are mentioned in relation to specific primary causes above, whereas the ones that are not related to one specific cause are discussed below.

The man-machine interface

One additional factor that may contribute to external communication failures and errors related to navigational equipment was the man-machine interface. The design of equipment and how information is shared between the user and the machine can affect the probability for failures because of how this limits the usage. These types of issues may be seen as included in the factor ”inadequate equipment”.

Personal actions or choice

Personal actions or choice was added as being contributory to an officer on watch being asleep and absent. The respondents meant that a personal decision can result in the unawareness. From the perspective of the authors and the system approach (refer to Section 3.2), there are very few decisions that can be classified as a personal choice, considering how a sufficient level of education, risk perception/acceptance and maybe even morals should be a responsibility of the organisation. This factor should therefore be included in the factor “organisational culture”.

Weather

Some respondents considered that the weather has an influence on other primary causes than mainly injuries and navigation, for example an officer being asleep. Bad weather (precipitation, waves etc.) is likely to increase the alertness on the bridge but will also make it more difficult to navigate and create a tiring environment. In that sense, weather conditions would be a factor in somebody falling asleep.

8.7 Summary of results

All results from the discussion above are summarised in Figure 15 below. The figure is based on the hierarchical model from Chapter 7 but is adjusted to reflect the results. Scenarios, primary causes and underlying factors that not play an important role with regards to the results are faded. Causes and factors which have not shown any clear tendencies are placed within brackets. The underlying factors are ranked after their importance according to the results, with the most contributing factor first.

The factors and causes that were identified and added by the participants during the interviews have all been acknowledged by one person each. Due to this, these factors and causes have not been analysed further even though it is possible that the factors may have a significant impact on the collision risk. Also refer to Section 9.1.

An underlying factor that is represented in several primary causes could be more important than one that only is connected to one primary cause. However this also depends on how important the specific primary cause is. The underlying factor will be regarded as insignificant if the primary cause does not affect the collision risk to a great extent.

Some underlying factors were identified to play an important role in several primary causes and are therefore considered to be significant areas when improvements and risk mitigation are to be undertaken. Examples of these areas are problems with not following guidance and an over reliance on technical equipment, which appears to be well-known hazards. A reoccurring focus area should also be the organisational culture on a ship, e.g. acceptance and understanding of actions and behaviors.

8.7.1 Comparison to RABL project

When comparing our results with the study in the RABL project the same three most important causes for lack of awareness (or watch keeping failure as referred to in the RABL project) are found; asleep, absent and absorbed. The RABL project shows that officer on watch being asleep has a probability around 100 times higher than absent and distraction. In this thesis it was found that sleep, absence and distraction have equal contribution to the scenario lack of awareness.

There are some differences between this thesis and the RABL project why all the results not are comparable. The RABL project was focused on evaluating data for risk analysis and did not discuss reasons to why the different causes occur, i.e. the underlying factors. Different assessments have been done in the RABL project depending on the type of ship, e.g. merchant ships and fishing vessels. The RABL project varied between using one to four experts in the assessments, which seems like a small selection if reliable values are going to be achieved.

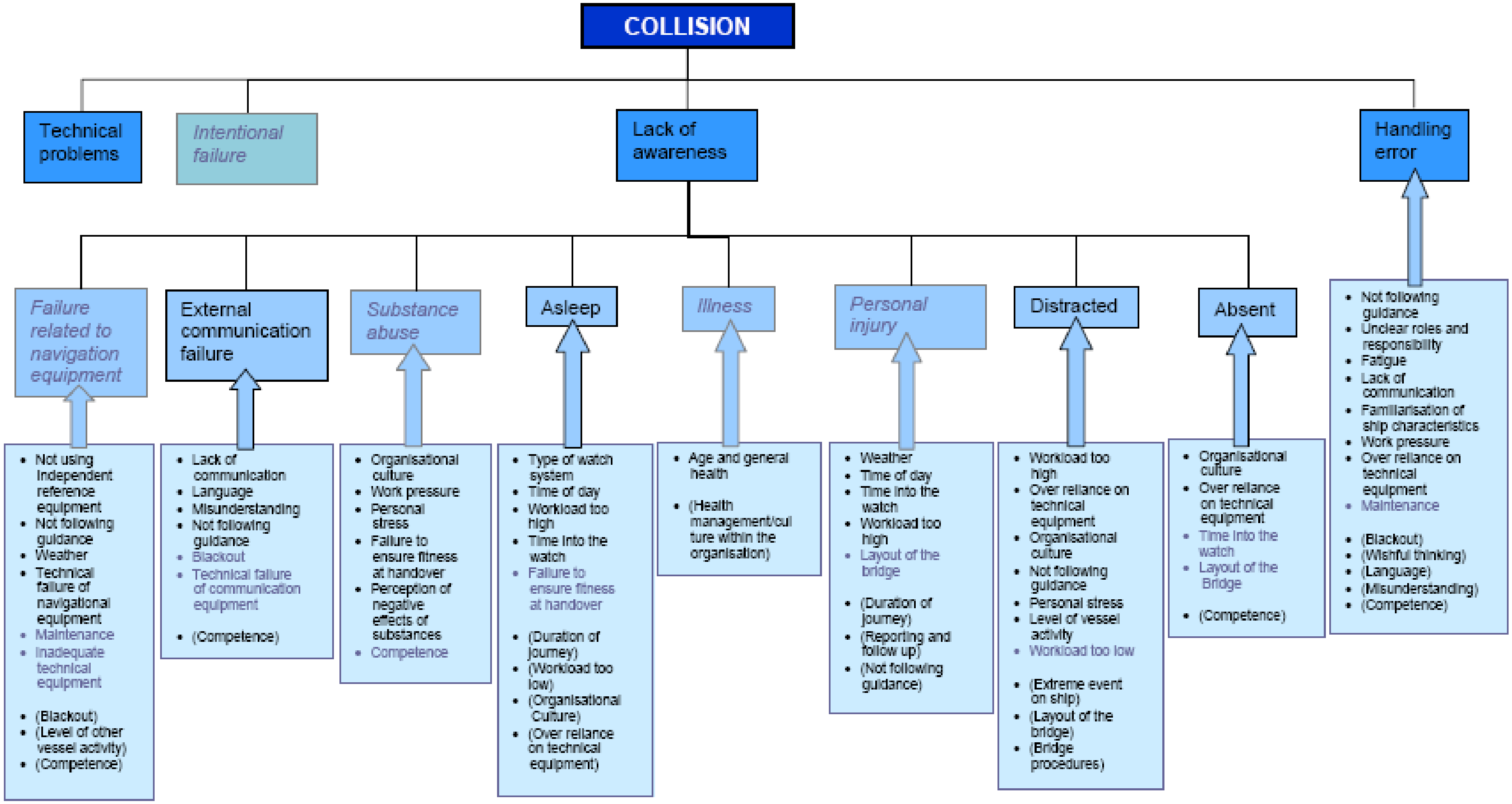


Figure 15: The model of scenarios, causes and factors updated with regards to the results.

9 Discussion

This chapter presents a discussion of uncertainties in the method and the analysis, including benefits and strengths.

It has been difficult to find a recognised method for combining a limited number of frequency data and previously made expert judgements with results from a new study. A structural model has therefore been used as a base, with a pursuit to find information from other areas when the area of research related to offshore collisions is lacking. It is likely that there is not a great deal of information about offshore ship collisions due to the risk being small when compared to other types of ship collisions.

There has been an attempt during the whole work process, namely that the final thesis will achieve three statements: that the examination is repeatable, that the methods and observations can be evaluated and that the intellectual process can be understood. This has been achieved by describing how the interviews were performed and which questions were asked. All answers are presented within the thesis together with statistics from where conclusions were drawn. This should give a transparent project that is possible to validate.

The geographical area where the conclusions from this thesis are applicable is mainly the North Sea but possibly also other areas with regulations and conditions similar to those of the North Sea. The work is not specific to the offshore industry but rather to the shipping industry in general.

9.1 Interviews and results

There was a small setback to the original plan when a valid sample of questionnaire respondents was not achieved. This may for example depend on the respondents' lack of time or that people in general are more willing to answer questionnaires when confronted in person. In hindsight, this was though probably the best outcome considering the many advantages of interviews. The interviews gave an opportunity to explain the hierarchical model, to define concepts and to ask the respondents questions.

Many conclusions can be drawn from the results with regards to the contribution of the causes and factors for the collision risk. It might although be possible that the opinions of the respondents are not reflected in such a way that was initially planned.

Subjectivity

Subjectivity is always a problem in interviews. Results are dependent on how researchers completing a project and expert groups interpret information. There are subjective values involved during interviews and also afterwards when the gathered information is assessed. There is also a possibility that respondents want to protect their colleagues and the reputation of their profession and therefore not always answer the questions truthfully. By comparing information from different sources, currently used models and expert judgement the results have been given validity by using triangulation.

Different backgrounds

Our wish was that the experience of the participants would provide the ability to look at a collision objectively and thus identify possible hazards and risk contributing factors. Some of the participants were able to apply a more open set of mind whereas others were less flexible. It was also noted that the participants had different frames of reference. The respondents came from different backgrounds and some of them had never worked onboard a ship in the specific area while others had never performed risk analyses. This has an impact on for example whether the respondents answered with the specific geographical area in mind or had a more global focus.

"*Humans have the reasonable expectation that the recurrences of the past provide a fair guide to the likelihoods of the future*" (Reason, 1988)

As remarked in the quote above, it was noticed that a few of the respondents mainly related to own experiences when answering questions, without trying to have a more generic focus. If something had happened to them, they were more likely to rate this cause or factor as high.

However, by considering the selection of interviewees with different backgrounds, that all in some way are connected to the maritime or offshore sectors, we believe that the some of the uncertainties incorporated in the expert judgement would diminish. The number of experts is substantial, with representation from active captains, former captains working in other areas, people within education in the maritime sector and researchers etc.

Different interpretations

During the completion of interviews, it became obvious that some of the inquires were difficult to understand and that the interpretation of the questions can vary depending on the respondents' frame of references.

Explanations of concepts would not guarantee that the participants of the study had the same views as the authors, but it would definitely increase the likelihood. We tried to be consistent and explain concepts during the interviews, so that the questions were approached from the same perspective and this should significantly have improved the results. Nevertheless, the explanations were not always adopted, maybe because of the difficulties to make a person totally embrace a new set of mind. It could also be possible that the participants answered questions without asking for clarifications. The results might have been clearer if the respondents had completely shared the views of all the definitions and were familiar with the structural model.

Diversities in results

Diversity between answers can be a sign of several things. It could be related to difficulties in understanding the questions, diverse interpretations of the questions or simply reflect varying opinions. An example of this is a question regarding "high workload" as an underlying factor to an officer on watch being distracted. One way to read the question is "if the workload is too high, to what extent would this contribute to the officer being distracted?". Our intention was that the question should be interpreted as "considering an officer on watch being distracted, to what extent has a high workload contributed to that distraction?". This problem became apparent during some of the interviews and it was unfortunately difficult to impact on. Sometimes it felt like the respondent had a bottom-up perspective rather than a top down view where the collision is the overlying starting point.

A tendency with regards to the underlying factors is that few extreme values were used during the rankings. Respondents seemed to prefer little contribution to significant contribution (i.e. 2, 3 or 4) if they were unsure, especially 3 - medium contribution. Some respondents pointed out the tendency to not choose extreme values, i.e. no contribution and very significant contribution.

The results are more than once evenly distributed, which makes it difficult to outline any distinct conclusions. Besides that, it is likely that the results from the expert study are influenced by the difficulty in achieving a categorisation that is perceived as totally obvious. How the underlying factors were complicated to divide into groups may also have been reflected in the respondents' answers. But the even distribution can also be a sign of an uncertain factor which is an important conclusion itself.

Factors added during the interviews

The factors added by participants in the interviews can be useful in future studies. It was noticed that many respondents found it difficult to add own factors after the ranking of the predetermined. We had probably obtained more factors if the respondents had the opportunity to reason independently, but with the likely consequence of incomparable results. A solution to this could have been to conduct a workshop with all experts instead of interviews, but this was not possible because of difficulty in coordinating this.

Correlations

The answers might also have been affected by correlation between various factors. It is not always easy to know where certain problems belong, which can be exemplified by the factors language and competence. Language can be seen as a component in competence (education, skills), but how would the question about contribution to communication be answered if there are difficulties in interpretations? A significant part of competence may involve language whereas the language skills also may be excluded and assessed separately. This is a problem that is inevitable, it is impossible to clarify all concepts to an extent that all people interpret them in the same way.

Correlation is also a problem when it comes to the categorisation made in Section 7.4 where one specific factor can belong to more than one category. Examples are familiarisation with ship characteristics and over reliance on technical equipment which are categorised as factors related to handling but that also could be categorised under organisational factors. Because of the uncertainties with the categorisation no conclusions of the different categories are drawn.

The two types of correlations can lead to the contribution of factors being over or under valuated.

9.2 Human and organisational factors – measuring the impacts

One common problem with measuring human and organisational factors is the area itself. It is often very difficult to grasp concepts and understand what parts that are correlated with or impacting on others. It may be challenging to agree on what human and organisational factors mean and there is often a discrepancy in definitions, with a consequence of predicaments when results from different projects are to be compared.

Another dilemma with trying to quantify actions and human errors is how humans are not predictable and that accidents often occur in several steps in a chain of events. This can result in problems when trying to quantify failures and factors. It can be hard to collect empirical data from the industry, as there often is inadequate information available. Even though there are several maritime accident databases, the data contained is only marginally relevant to human and organisational factors. Underlying factors are seldom mentioned in accident reports, considering that they are generally not analysed to that level of detail but are probably a part of all accidents.

It may sometimes be better to use qualitative discussions to assess the impact of human and organisational factors than quantitative, considering how this would allow for more of a discussion around the area in lieu of avoiding it. There is a danger with applying fixed values in risk analyses, without understanding and reflecting over what lies behind them. A qualitative discussion can therefore give more of an understanding of the area. We believe that it is better to try to penetrate the area than avoiding a measurement of human and organisational factors, considering that many sources mean that the impact of human errors is significant in accidents.

9.3 The literature review

There has been a strive towards finding literature that is applicable for our purpose but most research are dealing with the shipping industry and interactions within it or with the offshore industry but not the collision risk. We have drawn conclusions from research regarding collisions between two ships and groundings. Information has been applied with carefulness and the authors are well aware of the problems and uncertainties this might mean. It must however be kept in mind that there also is a great advantage with adopting methods and information from other areas considering that this can provide new knowledge.

Statistical data

It is challenging to predict scenarios and accidents that do not occur very often by just looking at statistics and incident frequencies, considering that this might not give a picture of the actual risk. If few accidents have occurred, like in the case with offshore collisions, this could indicate a too low frequency. It could also be possible that the risk is predicted as more significant when looking at historical data, as more accidents could have occurred previously than nowadays. A change over time could depend on advances in technology, such as traffic surveillance stations.

One finding during the literature review was the big divergence between accident data bases. The sources seem to have their own way to describe and categorise data, which results in big disadvantages when comparing statistics. Causes to accidents are also of great importance for preventive measures undertaken. If reasons behind accidents are not addressed properly, it could result in risk mitigating measures that are inadequate. Near misses are of great importance, especially within the offshore industry where the experiences from collisions is relatively small. Accident data bases are generally not related to traffic patterns. Changes in traffic density, routes or type of ships can affect the risk for an accident and this is important to keep in mind when using accident data.

10 Conclusion

This chapter describes how the purpose of the thesis was fulfilled, followed by answers of the research questions. Thoughts and ideas for future work that are perceived as important are also outlined.

10.1 Reaching the purpose

The purpose of this thesis was to achieve a better understanding of why a collision between a ship and an offshore installation occur and to identify the most influential factors in the accident development. This is achieved by creating a hierarchical model of a collision, including scenarios, primary causes and underlying factors. It was hereby possible to grasp the chain of events with several factors that together contribute to a primary cause, which by slipping through numerous layers of risk mitigating barriers may result in a collision.

10.2 Answering the research questions

The research questions answered during the work with the thesis are:

- *What are the primary causes and underlying factors behind a ship collision with an offshore installation?*

  The levels of causes and factors in a collision were identified from the literature review combined with small workshops. The study is altogether based on the hierarchical model delineated during the development of this thesis. The model can be found in Figure 12 (p.41) and shows all identified scenarios, causes and underlying factors.

- *To what extent do these identified primary causes and underlying factors contribute to the collision risk?*

  The scenario with most contribution to the collision risk is recognised to be awareness failure with asleep, absence and distraction as the most contributing causes. The conclusions following the interviews and information from research are illustrated in Figure 15 (p.58), where the most contributory causes and factors are pointed out. It is also possible to see factors that are regarded as not important.

- *How can this deeper understanding of collisions be used, both integrated when assessing collision risk and generally in the maritime sector?*

  Conclusions from this thesis can be applied in offshore collision risk analyses where the results together with further research can contribute to an update of existing collision risk models. This project also shows that it is important to update the collision risk models with regards to new technical equipment, organisational changes etc.

The maritime industry can benefit from this research when trying to identify hazards in e.g. risk analyses and work place safety assessments. This project can also be used to better understand human and organisational factors including uncertainties, especially in disciplines that normally are very quantitative.

10.3 Future work

To make sure that the results can be useful in for example risk analyses, some further work needs to be done.

- Additional research should be undertaken in the area of the identified major contributory factors. These can be further assessed hence leading to more accurate reflection of the risk.
- There is a need for consistency in discussing human and organisational factors, which especially is identified to be necessary within accident investigations and definitions of factors.
- More detail should be provided in accident databases, to give a better understanding of how different factors contribute to an accident. A focus on near misses and a deeper discussion of underlying factors could help facilitate more proactive work with hazards and risks.

11 References

11.1 Literature

Alvik, S. (2000), *The perception of safety management within shipping companies*, The Royal institution of naval architects, RINA international conference London 27-29 September, United Kingdom.

Atwell, C., Pourzanjani, M., Pearce, D. (1996), *User requirements for new navigation systems*, The international conference on preventing collision at sea, Collision '96, Hill Taylor Dickinson seminar on maritime collision.

Aven, T. & Pitblado, R. (1998) On risk assessment in the petroleum activities on the Norwegian and UK continental shelves. *Reliability Engineering & System Safety,* Issue 61, pp.21-29.

Aven T. & Vinnem J-E. (2005) On the use of risk acceptance criteria in the offshore oil and gas industry, *Reliability Engineering & System Safety,* Issue 90, pp.15-24.

Backman, J. (2008), *Rapporter och uppsatser*, Studentlitteratur, Pozkal, Poland. (in Swedish)

Baker, C.C. & McCafferty, D.B. (2005), *Accident database review of human element concerns: what do the results mean for classification?*, ABS (American Bureau of shipping) technical papers 2005, USA.

Baker, C.C. & Seah, A.K. (2004), *Maritime Accidents and Human Performance: the Statistical Trail,* ABS (American Bureau of shipping) technical papers 2005, USA.

Bertranc (2000), *Final consolidated progress report*, Brussels, Belgium.

Brown A. & Haugene, B. (1998), *Assessing the impact of human and organisational factors on the risk of tanker grounding*, 8th International Off shore and Polar Engineering Conference, Paper No ISOPE-98-HKP-03, May 1998.

Bryant, D.T. (1991), *The human element in shipping casualties*, Department of transport, Marine Directorate, United Kingdom.

Dekker, S. (2002), *The re-invention of human error*, Technical Report 2002-01, Lund University School of Aviation, Ljungbyhed, Sweden.

De la Campa Portela, R., Rodríguez Gómez, B. A., López, M., Rivero Martínez, B. (2006) Study in Application of natural language processing in maritime communications, *Journal of Maritime Research*, Vol. 3, No. 3, pp.19-36.

DNV Technica (1995), *Update of the UKCS Risk Overview OTH94 458*, Health and Safety Executive Offshore Technology Report.

DNV (1998), *Appendix X – Risk Analysis of Collisions. A Guide to Offshore QRA*, Oslo, Norway.

Ejvegård, R. (2008), *Vetenskaplig metod*, Studentlitteratur, Lund, Sweden. (in Swedish)

Embrey, D.E. (1992), Incorporating management and organisational factors into probabilistic safety assessment, *Reliability Engineering and System Safety*, Vol. 38, pp.199-208.

Friis-Hansen, P. & Simonsen B.C. (2002) GRACAT: software for grounding and collision risk analysis, *Marine Structures*, Vol. 15, pp. 383-401.

Golafshani, N. (2003), Understanding reliability and validity in qualitative research, *The Qualitative report*, Vol. 8, No. 4, 2003.

Grech, M., Horberry, T., Koester, T. (2008), *Human factors in the maritime domain*, CRC Press. New York, USA.

Grozdanović, M. & Stojiljković, E. (2006) Framework for human error quantification, *Philosophy, Sociology and Psychology*, Vol. 5, Issue 1, pp. 131-144.

Harstad, E. (1991), *Safety as an integrated part of platform design*, Paper presented at the 1st International Conference on Health, Safety and Environment, The Hague, 10-14 November 1991.

Haugen, S. (1991), *Probability evaluation of frequency of collision between ships and offshore platforms*, Ph.D. Thesis, Norwegian University of Science and Technology.

Hetherington, C., Flin, R., Mearns, K. (2006), Safety in shipping: The human element, *Journal of safety research*, No. 37, pp. 401-411.

HSE (1999), *Effective Collision Risk Management for offshore installations*, Offshore technology report, OTO 1999 052, Health and Safety Executive, United Kingdom.

HSE (2003), *Ship/platform collision incident database*, Prepared by Serco Assurance. Research Report 053, Health and Safety Executive United Kingdom.

Håvold, J.-I. (2007), *From Safety Culture to Safety Orientation - Developing a tool to measure safety in shipping*, Doctoral thesis Norwegian University of Science and Technology, Trondheim Norway.

IMO (1995), *International Convention on Standards of Training, Certification and Watchkeeping for Seafarers,* International Maritime Organisation*.*

IMO (1999), *Principles of safe manning*, Resolution A.890 (21), International Maritime Organisation.

IMO (2007), *Formal Safety Assessment. Consolidated text of the Guidelines for Formal Safety Assessment for use in the IMO rule-making process.* Maritime Safety Committee, International Maritime Organisation.

Kaplan, S. (1997), The words of Risk Analysis, *Risk Analysis,* Vol. 17, Issue 4, pp. 407-417.

Kristiansen, S. & Soma, T. (1999), *Effectiveness of Safety Measures in Maritime Operations*, Norwegian university of science and technology, division of marine systems design, Trondheim, Norway.

Lang, J. (2000), An Accident investigator's perspective, The marine Accident Investigation Branch, The Royal institution of naval architects, RINA international conference 27-29 september, London, United Kingdom.

Lützhöft, M. & Dekker S. (2002), On your watch - Automation on the bridge, *Journal of navigation*, Vol. 55, Issue1, pp. 83-96.

Lützhöft, M. & Kiviloog, L. (2003), *Sjöfartsdagen 2003: Kommenterade voteringsresultat*, Ångfartygsbefälhavare-sællskapet i Stockholm (in Swedish).

Lützhöft, M., Thorslund, B., Kircher, A., Gillberg, M. (2007), *Fatigue at Sea – A field study in Swedish shipping*, VTI report 586 A, Linkøping.

MAIB (2004), *Bridge watchkeeping safety study*, Marine accident investigation branch, safety study 1/2004, United Kingdom.

Maritime & Coast Guard Agency (2006), *Organizational Structures: The Influence of Internal and External Structureson Safety Management Performance*, A review prepared by Greenstreet Berman, Research Project 547, United Kingdom.

McCafferty, D.B. & McSweeney, K.P. (2003), *Human Factors Engineering and Cultural Calibration for Vessel and Offshore Installation Design*, ABS Technical papers 2003, American Bureau of Shipping.

McCallum, M.C., Raby, M., Rothblum, A.M. (1996), *Procedures for investigating and reporting human factors and fatigue contributions to marine casualties*, U.S. Department of Transportation, U.S. Coast Guard Report No CG-D-09-97.

National research council (1990), *Crew Size and Maritime Safety*, National Academy Press, Washington DC, USA.

Nielsen, D & Jungnickel, D. (2003) Maritime Accident Investigation and Temporal Determinants of Maritime Accidents: A Case Study of East-German Records, *WMU Journal of Maritime Affairs* Vol. 2, Issue 1, pp. 49-59.

NPD (2008a), *Fakta Norsk Petroleumverksemd*, Oil and Energy Department & Norwegian Petroleum Directorate, Stavanger, Norway. (in Norwegian)

Patraiko, D. (2006), Fatigue onboard. Raising awareness: The Nautical Institute Reporting Plan. *Seaways,* March 2006.

PSA (2008a), *Risikonivå i Petroleumvirksomheten - Norsk sokkel 2007,* Petroleum Safety Authority, Stavanger, Norway. (in Norwegian)

PSA (2008b), *Sikkerhet - Status og Signaler 2007-2008*, Petroleum Safety Authority, Stavanger, Oslo. (in Norwegian)

Philips, R. (2000), Sleep, watchkeeping and accidents: a content analysis of incident at sea reports, *Transportation Research* Part F3, pp.229-240.

Reason, J. (1988), Cognitive aids in process environments: prostheses or tools? In E. Hollnagel, G et al. *Cognitive engineering in complex dynamic worlds*, Academic Press, London, United Kingdom.

Reason, J. (2000), Human error: models and management, *British medical journal*, Vol. 320, pp.768-770.

Smith, A. (2001), Offshore *fatigue: A study of ships in the offshore oil industry*, paper presented at the SIRC second symposium, Cardiff University.

Smith, E. (1995), Risk management in the North Sea offshore industry: history, status and challenges. 45th IAF Conference, *Acta Astronautica*, Issue 37, pp. 513-523.

SSPA (2008), *Methodology for Assessing Risk to Ship Traffic from Offshore Wind Farms*, Vind-Pilot Report. Funded by Vattenfall AB and Swedish Energy Agency, Sweden.

Technica (1987), *Risk assessment of Buoyancy Loss*, Ship-modu collision frequency, Report No 3, Trondheim.

TSB (1998), *A safety study of the operational relationship between ship masters/watchkeeping officers and marine pilots*, Transportation Safety Board of Canada (TSB), Report number SM9501A.

US Coast Guard (1995), *Prevention through people: Quality action team report*, Washington DC.

Vinnem, J-E. (2007) *Offshore Risk Assessment- Principles, Modelling and Applications of QRA Studies*, Springer, London.

Wang, J. & Zhang, S.M. (2000), Management of human error in shipping operations, *Professional Safety*, Section: Human factors, No. 10, pp. 23-28.

11.2 Electronic references

HSE (2008a), Health and Safety Executive, http://www.hse.gov.uk/offshore/who.htm, 2008-10-12.

HSE (2008b), Health and Safety Executive, http://www.hse.gov.uk/pubns/indg189.pdf, 2008-11-12.

IEA (2008), The International Ergonomics Association, http://www.iea.cc/browse.php?contID=what_is_ergonomics, 2008-10-23.

IMO (2008), International Maritime Organisation, http://www.imo.org/, 2008-10-12.

Luleå University Library (2008), http://www.luth.se/depts/lib/databaser/artiklar.shtml, 2008-10-09 (only in Swedish)

MAIB (2008), Marine Accident Investigation Branch, http://www.maib.gov.uk/publications/safety_digests.cfm, 2008-11-21.

Marine Profile (2008), http://www.marine-profile.com/, 2008-11-18.

NMD (2008), Norwegian Maritime Directorate, http://www.sjofartsdir.no/en/About_the_Norwegian_Maritime_Directorate, 2008-10-21.

NPD (2008b), Norwegian Petroleum Directorate, http://www.npd.no/NR/rdonlyres/82610E1F-9948-4966-B482-5573267F346D/13108/Letebor_avsl_2006e.jpg, 2008-11-18.

PSA (2008c), Petroleum Safety Authority, http://www.ptil.no/about-us/category89.html, 2008-11-21.

PSA (2008d), Petroleum Safety Authority, http://www.ptil.no/regulations/category87.html, 2008-11-23

Swedish Maritime Administration (2008a), http://www.sjofartsverket.se/templates/SFVXPage____1041.aspx , 2008-11-18.

Swedish Maritime Administration (2008b), http://www.sjofartsverket.se/templates/SFVXPdfView____2965.aspx, 2008-11-20.

The University of Gothenburg (2008), http://www.infovoice.se/fou/bok/10000035.htm, 2008-10-15.

The University of Mälardalen (2008), http://www.eki.mdh.se/personal/mlc01/metod_0_7/Validitetochreliabilitet.html, 2008-10-15.

UKOOA (2008), The United Kingdom Offshore Operators Association, http://www.ukooa.co.uk/issues/piperalpha/v0000864.cfm, 2008-11-12.

US Coast Guard (2008), http://www.navcen.uscg.gov/, 2008-11-18.

Appendix A – Interview Guide

Introduction

The purpose of this interview is to investigate the reasons behind collisions between ships and offshore installations. The interview will identify and rank all underlying factors that can affect a collision. The study excludes collisions between offshore vessels and their dedicated offshore installations. The questionnaire considers all types of ships that may be present in the North Sea, such as merchant vessels, cruise ships, fishing ships and supply boats (i.e. during the travel towards/away from other offshore installations).

The scale ranges from 1 to 5, where the grade 5 means that a cause has very significant contribution whereas 1 means no contribution, according to the scale below.

Scale	1	No contribution
	2	Little contribution
	3	Medium contribution
	4	Significant contribution
	5	Very significant contribution

We are very thankful for your participation in this study!

Regards,
Karin af Geijerstam
Hanna Svensson

Background information

Age ------------

Occupation/rank --

Experience
- Time at sea, brief work description, type of ship
  or/and
- Experience from research or projects concerning e.g. ship collisions, human factors or risk analysis

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Questions

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1. Considering collisions between ships and offshore installations, to what extent do you think that the following scenarios contribute?

	1 No contribution	2	3	4	5 Very significant contribution
a.) Technical failure E.g. steering failure or machinery breakdown that prevents the ship from changing course	☐	☐	☐	☐	☐
b.) Lack of awareness on ship The crew is unaware of the offshore installation and the collision course (e.g. due to sleep, absence, distraction)	☐	☐	☐	☐	☐
c.) Handling error in collision avoidance The crew is aware of the offshore installation but somehow fails to avoid collision	☐	☐	☐	☐	☐
d.) Intentional failure Somebody on the ship aims to collide with an offshore installation	☐	☐	☐	☐	☐
e.) Other, please specify:	☐	☐	☐	☐	☐

----

2. Considering collisions, to what extent do you think the following causes contribute to <u>lack of awareness on ship</u> (the crew is unaware of the offshore installation and the collision course)**?**

	1 No contribution	2	3	4	5 Very significant contribution
<u>Equipment related issues:</u>					
- Failure related to navigational equipment (*Failure of the equipment or failure when using the equipment)*	☐	☐	☐	☐	☐
- External communication failure (*Failure of communication equipment or failure when receiving/interpreting information from an installation, other vessels or land-based stations)*	☐	☐	☐	☐	☐
- Other, please specify:	☐	☐	☐	☐	☐

	1	2	3	4	5
<u>Officer on the watch being:</u>					
- Incapacitated by substance abuse	☐	☐	☐	☐	☐
- Asleep	☐	☐	☐	☐	☐
- Incapacitated by illness	☐	☐	☐	☐	☐
- Incapacitated by personal injury	☐	☐	☐	☐	☐
- Distracted	☐	☐	☐	☐	☐
- Absent from bridge	☐	☐	☐	☐	☐
- Other, please specify:	☐	☐	☐	☐	☐

Awareness failure
The crew is unaware of the offshore installation and the collision course

In an awareness failure, to what extent do you think that these underlying factors contribute to the following scenarios (3-10)?

3. Officer on watch is present but incapacitated due to substance abuse:

	1 No contribution	2	3	4	5 Very significant contribution
a) Competence	☐	☐	☐	☐	☐
b) Failure to ensure fitness at handover	☐	☐	☐	☐	☐
c) Perception of negative effects from substances	☐	☐	☐	☐	☐
d) Organisational culture	☐	☐	☐	☐	☐
e) Work pressure	☐	☐	☐	☐	☐
f) Personal stress	☐	☐	☐	☐	☐
g) Other, please specify:	☐	☐	☐	☐	☐

4.) Officer on watch is present but incapacitated due to a personal injury:

	1 No contribution	2	3	4	5 Very significant contribution
a) Layout of the bridge	☐	☐	☐	☐	☐
b) Weather	☐	☐	☐	☐	☐
c) Reporting and follow up	☐	☐	☐	☐	☐
d) Workload too high	☐	☐	☐	☐	☐
e) Time into the watch	☐	☐	☐	☐	☐
f) Time of day	☐	☐	☐	☐	☐
g) Duration of journey	☐	☐	☐	☐	☐
h) Not following guidance	☐	☐	☐	☐	☐
i) Other, please specify:	☐	☐	☐	☐	☐

5.) Officer on watch is present but incapacitated due to illness:

	1 No contribution	2	3	4	5 Very significant contribution
a) Age and general health	☐	☐	☐	☐	☐
b) Health management/culture within organisation	☐	☐	☐	☐	☐
c) Other, please specify:	☐	☐	☐	☐	☐

6.) Officer on watch is present but distracted:

	1 No contribution	2	3	4	5 Very significant contribution
a) Extreme event on ship	☐	☐	☐	☐	☐
b) Over reliance on technical equipment	☐	☐	☐	☐	☐
c) Workload too high	☐	☐	☐	☐	☐
d) Workload too low	☐	☐	☐	☐	☐
e) Level of other vessel activity	☐	☐	☐	☐	☐
f) Layout of the bridge	☐	☐	☐	☐	☐
g) Bridge procedures	☐	☐	☐	☐	☐
h) Organisational culture	☐	☐	☐	☐	☐
i) Not following guidance	☐	☐	☐	☐	☐
j) Personal stress	☐	☐	☐	☐	☐
k) Other, please specify:	☐	☐	☐	☐	☐

7.) Officer on watch is present but asleep:

		1 No contribution	2	3	4	5 Very significant contribution
a)	Workload too high	☐	☐	☐	☐	☐
b)	Workload too low	☐	☐	☐	☐	☐
c)	Failure to ensure fitness at handover	☐	☐	☐	☐	☐
d)	Organisational culture	☐	☐	☐	☐	☐
e)	Over reliance on technical equipment	☐	☐	☐	☐	☐
f)	Time into the watch	☐	☐	☐	☐	☐
g)	Time of day	☐	☐	☐	☐	☐
h)	Duration of journey	☐	☐	☐	☐	☐
i)	Type of watch system	☐	☐	☐	☐	☐
j)	Other, please specify:	☐	☐	☐	☐	☐

8.) Officer on watch is absent:

	1 No contribution	2	3	4	5 Very significant contribution
a) Competence	☐	☐	☐	☐	☐
b) Organisational culture	☐	☐	☐	☐	☐
c) Over reliance on technical equipment	☐	☐	☐	☐	☐
d) Layout of the bridge	☐	☐	☐	☐	☐
e) Time into the watch	☐	☐	☐	☐	☐
f) Other, please specify:	☐	☐	☐	☐	☐

9.) Failure related to navigation equipment:

	1 No contribution	2	3	4	5 Very significant contribution
a) Competence	☐	☐	☐	☐	☐
b) Not using independent reference equipment	☐	☐	☐	☐	☐
c) Maintenance	☐	☐	☐	☐	☐
d) Level of other vessel activity	☐	☐	☐	☐	☐
e) Weather	☐	☐	☐	☐	☐
f) Blackout	☐	☐	☐	☐	☐
g) Technical failure of navigational equipment	☐	☐	☐	☐	☐
h) Inadequate technical equipment	☐	☐	☐	☐	☐
i) Not following guidance	☐	☐	☐	☐	☐
j) Other, please specify:	☐	☐	☐	☐	☐

10.) External communication failure:

	1 No contribution	2	3	4	5 Very significant contribution
a) Competence	☐	☐	☐	☐	☐
b) Language	☐	☐	☐	☐	☐
c) Lack of communication	☐	☐	☐	☐	☐
d) Technical failure of communication equipment	☐	☐	☐	☐	☐
e) Misunderstanding	☐	☐	☐	☐	☐
f) Blackout	☐	☐	☐	☐	☐
g) Not following guidance	☐	☐	☐	☐	☐
h) Other, please specify:	☐	☐	☐	☐	☐

Handling error
The crew is aware of the offshore installation but somehow fails to avoid collision.

11. In a handling error, to what extent do you think that these underlying factors contribute?

	1 No contribution	2	3	4	5 Very significant contribution
a) Competence	☐	☐	☐	☐	☐
b) Over reliance on technical equipment	☐	☐	☐	☐	☐
c) Maintenance	☐	☐	☐	☐	☐
d) Blackout	☐	☐	☐	☐	☐
e) Familiarisation of ship characteristics	☐	☐	☐	☐	☐
f) Work pressure	☐	☐	☐	☐	☐
g) Not following guidance	☐	☐	☐	☐	☐
h) Wishful thinking	☐	☐	☐	☐	☐
i) Lack of communication	☐	☐	☐	☐	☐
j) Language	☐	☐	☐	☐	☐
k) Misunderstanding	☐	☐	☐	☐	☐
l) Unclear roles and responsibility	☐	☐	☐	☐	☐
m) Fatigue	☐	☐	☐	☐	☐
n) Other, please specify:	☐	☐	☐	☐	☐

Thank you!

Appendix B – Expert group

Name	Organisation	Relevant experiences
Tor Einar Berg	Ship and Ocean Laboratory MARINTEK, Trondheim, Norway	Principal Research Engineer Research and development related to: Training of seafarers Knowledge testing – STCW 95
Emil Aall Dahle	Safetec Nordic AS, Oslo, Norway	Senior Safety Consultant Dr Ing
John Douglas	DNV SeaSkill, Oslo, Norway	Consultant 15 years at sea 10 years of human risk analysis
Åsa Ek	Aerosol and Ergonomics, University of Lund, Lund, Sweden	Research associate/PhD Developed an evaluation tool for safety culture in a passenger shipping setting. Collected empirical data on safety culture by applying the tool onboard six vessels in international traffic (Swedish crews).
Thomas Eriksen	Safetec Nordic AS, Oslo, Norway	Senior Safety Consultant 8 years of work with ship collision models, traffic studies and risk assessment.
Frank Lamberg Nielsen	Maersk Training Centre A/S, Svendborg, Denmark	Maritime Instructor Chief mate/captain 20 years at sea – container vessels, ferries, sailing boats.
Arve Lerstad	Ship Maneuvering and Simulator Centre, Trondheim, Norway	Project Manager Chief officer at chemical tanker Investigation manager of collisions between ships and installations 1986-2000 Thesis in "ship maneuvering capabilities" at NTNU (1981)
Stefan Lindberg	Active captain, Malmö, Sweden	Captain At sea for 35 years, of which 24 as a captain Cargo tankers, ferries, cruise ships, carry
Michael Manuel	World Maritime University (WMU), Malmö, Sweden	University lecturer, former ship captain 11 years at sea, ship captain on ocean going ships PhD in risk control, research in human factors and maritime casualty research
Egil Pedersen	Marine Technology, Norwegian University of Science and Technology (NTNU), Trondheim, Norway	Professor in Marine Technology (nautical science) Approximately 1 year at sea, including fishing vessels and seismic research vessels Research concerning collision avoidance: Approximately 4 years at Kobe University and the National Maritime Research Institute in Japan.
Tor Egil Hopen Saue	StatoilHydro, Bergen, Norway	Leader StatoilHydro Marin Master Mariner, working at different types of ship

		before StatoilHydro. Development of the StatoilHydro Traffic Surveillance Center
Helge Samuelsen	Ship Maneuvering and Simulator Centre, Trondheim, Norway	Captain and senior instructor at SMSC 30 years at sea, of which 12 as a captain. Various types of ships; tankers, dry cargo, bulk etc. 16 years experience as simulator instructor on various types of training including human factor training. Participated in several risk analyses regarding risk of collision
Steven Sawhill	DNV SeaSkill, Oslo, Norway	Project Manager 16 years as a captain at US Coast Guard ships Research: search and rescue, emergency response and emergency preparation
Jens-Uwe Schrøder	World Maritime University (WMU), Malmö, Sweden	Associate professor, last rank at sea was 2nd officer 3 years at sea over a period of 12 years, starting from cadet on general cargo ships, then AB and then 2nd officer. Experience on general cargo, container, coastal and chemical tanker.
Torkel Soma	DNV Maritime Solutions, Oslo, Norway	Principal safety consultant PhD concerning maritime safety cultures
Jan Erik Vinnem	Preventor, Stavanger, Norway	Specialist Advisor Risk Management M.Sc. in Naval Architecture and Marine Engineering Dr.ing. in System Safety Engineering; The Norwegian University of Science and Technology, Trondheim.
David Wendel	DNV SeaSkill, Oslo, Norway	Project Manager/Master Mariner 19 years of Maritime experience Onboard experience from container, tankers, RO-RO, high-speed, cruise ships
Carl-Henric Wulff	Former captain, Malmö, Sweden	Master Mariner, ashore since 4 years Cargo ships, hoover crafts, containers, tankers, ro-ro in the North of Europe
Petter Øverås	Ship Maneuvering and Simulator Centre, Trondheim, Norway	Captain and Project Manager 18 years at sea, of which 8 as a captain. Mainly on large LNG tankers. 12 years as instructor in a ship handling simulator 10 years in commercial cargo and shipping operations (ashore)

Appendix C – Explanations

AIS	Automatic Identification System. A broadcasting system that transmits ship information e.g. identity, position, speed, size, cargo etc. AIS is generally required to be fitted aboard all ships of over 300 gross and all passenger ships. AIS is also required on all ships engaged in international voyages. (HSE, 2007)
ECDIS	Electronic Chart Display Information System
FPSO	Floating Production, Storage and Offloading vessel. A floating tank system that is used in the offshore oil and gas industry to load, process and store the oil or gas until it can be offloaded to a tanker or sent through a pipeline.
GPS	Global Positioning System
HSE	Health and Safety Executive (UK)
ISM-code	International Safety Management Code. The purpose of the Code is to provide an international standard for the safe management and operation of ships and for pollution prevention.
MARPOL	International Convention for the Prevention of Pollution from Ships
Merchant vessel	A merchant vessel is a ship that transports cargo and passengers. Most countries of the world operate fleets of merchant ships. However, due to the high costs of operations, today these fleets are in many cases sailing under the flags of nations that specialize in providing manpower and services at favorable terms.
NPD	Norwegian Petroleum Directorate (Oljedirektoratet in Norwegian) is an independent State administration body
Piper Alpha incident	A large production platform, started operation in 1976. There was a massive leakage of gas condensate in 1988 which caused an explosion that led to large oil fires. The heat ruptured the riser of a gas pipeline from another installation. This produced a further massive explosion and fireball that engulfed Piper Alpha. 167 people died, 62 people survived within 22 minutes. (UKOOA, 2008)
PSA	Petroleum Safety Authority.

Safety zone	An area extending 500m from any part of an offshore installation. It is an offence towards the Petroleum Act (1987) to enter a safety zone except under special circumstances. (HSE, 2008b)
SBV/ERRV	A Stand-by vessel or Emergency Response Rescue Vessel provides warning, control and rescue services to an offshore installation. The ship e.g. notifies vessels that are on collision course and also assist in an evacuation.
SOLAS	International convention for the safety of life at sea.
STCW	International convention on standards of training, certification and watchkeeping for seafarers.
Supply vessel	A ship specially designed to supply offshore installation. It's primary tasks are transportation of goods and personnel.
VHF	Very High Frequency. Marine radio communication for ships. Channel 16 is used as the international calling and distress channel.
Waypoint	A coordinate used to identify a physical location in navigation. It has previously been common to use offshore installations as waypoint, but the scenarios seem to be less usual.

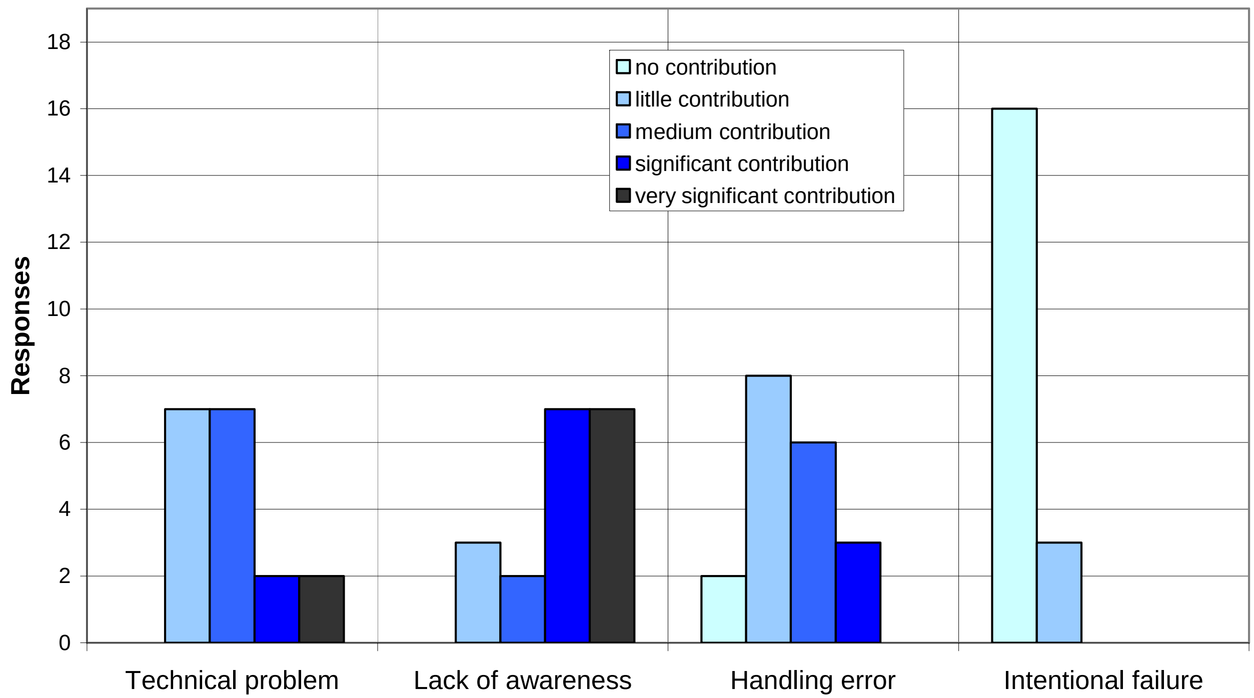
Appendix D – Definitions of concepts

Concepts	Definition
Absent from bridge	Officer on watch is absent (i.e. not present at bridge).
Age and general health	Conditions specific to the characteristics of an individual.
Asleep	Officer on watch is present but asleep
Blackout	There is no power supply.
Bridge procedures	Inadequate standards and procedures for the operations on the bridge.
Competence	The ability to perform a specific task, action or function successfully, which can be developed from training, education and experience.
Distracted	Officer on watch is present but distracted
Duration of journey	The time the crew spends on the vessel including tasks before departure and after arrival.
External communication failure	Failure of communication equipment or failure when receiving/interpreting information from an installation, other vessels or land-based stations.
Extreme event on ship	An event that draws the attention away from the normal procedures of the bridge, e.g. fire, man overboard
Failure of technical navigational equipment	Failure restricted to the technical navigation equipment. All errors related to human handling are excluded.
Failure related to navigational equipment/process	Failure of the equipment or failure when using the equipment.
Failure to ensure fitness at handover	The person handing over the watch fails to recognise that the next person of the watch is unfit for the task.
Familiarisation with ship characteristics	Familiarity with the character of the ship, such as size, response, equipment etc.
Fatigue	A condition of tiredness that reduces a person's ability to act.
Handling error in collision avoidance	The crew is aware of the offshore installation but somehow fails to avoid collision
Health management/culture within organisation	The general health management within the organisation with regards to the acceptance of medical conditions and procedures such as medical check-ups.
Inadequate technical equipment	The standard or type of technical equipment does not fulfil its purpose or the equipment is lacking.
Incapacitated by accident	Officer on watch is incapacitated by accident (e.g. personal injury)
Incapacitated by illness	Officer on watch is incapacitated by illness
Incapacitated by substance abuse	Officer on watch is incapacitated by substance abuse
Intentional failure	Somebody on the ship aims to collide with an offshore installation
Lack of awareness on ship	The crew is unaware of the offshore installation and the collision course (e.g. due to sleep, absence, distraction)

Lack of communication	No/not enough communication in a situation.
Language	Barriers that prevents or interfere in communication.
Layout of the bridge	The design does not fully enable the procedures of the bridge.
Level of other vessel activity	The density and/or the activities of the surrounding vessels.
Maintenance	Inadequate management standards and procedures within the organisation.
Misunderstanding	A failure to understand or a disagreement.
Not using independent reference equipment	Available reference equipment for navigation is not being used.
Not following guidance	Not following orders, guidelines, legislation etc.
Over reliance on technical equipment	High level of technical automation results in the officer on watch underestimating his/hers role in managing the ship.
Organisational culture	Common values and ideas that are shared within the organisation.
Perception of negative effects from substances	The person of the watch does not perceive that the substance will impede their awareness abilities.
Personal stress	Stress not related to work environment, e.g. family conditions.
Reporting and follow up	Procedures for reporting of incidents and near-misses and how these are followed up.
Technical failure	E.g. steering failure or machinery breakdown that prevents the ship from changing course
Technical failure of communication equipment	Failure restricted to the technical communication equipment. All errors related to human handling are excluded.
Technical failure of navigation equipment	Failure restricted to the navigation equipment. All errors related to human handling are excluded.
Time into the watch	The duration of the watches.
Time of day	Day or night.
Type of watch system	The type of watch system that is used in organisation, e.g. what is the proportion between hours of work and hours of free time. Examples are 4/8 and 6/6 systems. (work/free)
Unclear roles and responsibility	There is a misunderstanding with regards to who has the responsibility of the bridge, e.g. due to inadequate hand-over briefings.
Weather	Weather conditions such as waves, precipitation etc.
Wishful thinking	The person of the watch remains inactive and hopes that the hazard will be avoided without actions.
Workload too high	High amount of tasks that are to be performed during the watch.
Workload too low	Boredom caused by too few tasks.
Work pressure	The work environment is perceived to be stressful, e.g. due to economic pressure or time pressure.

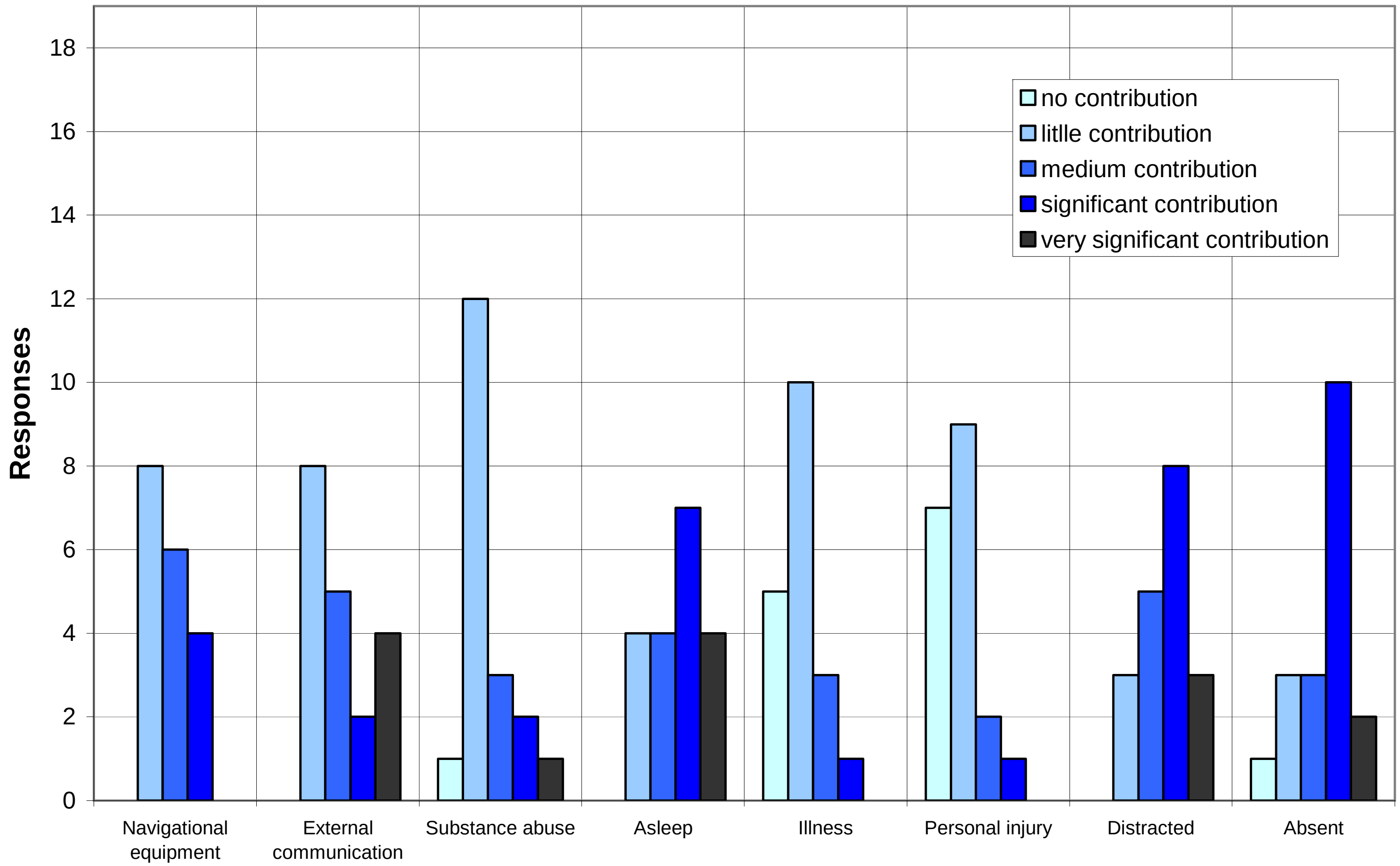
Appendix E – Results: scenarios and primary causes

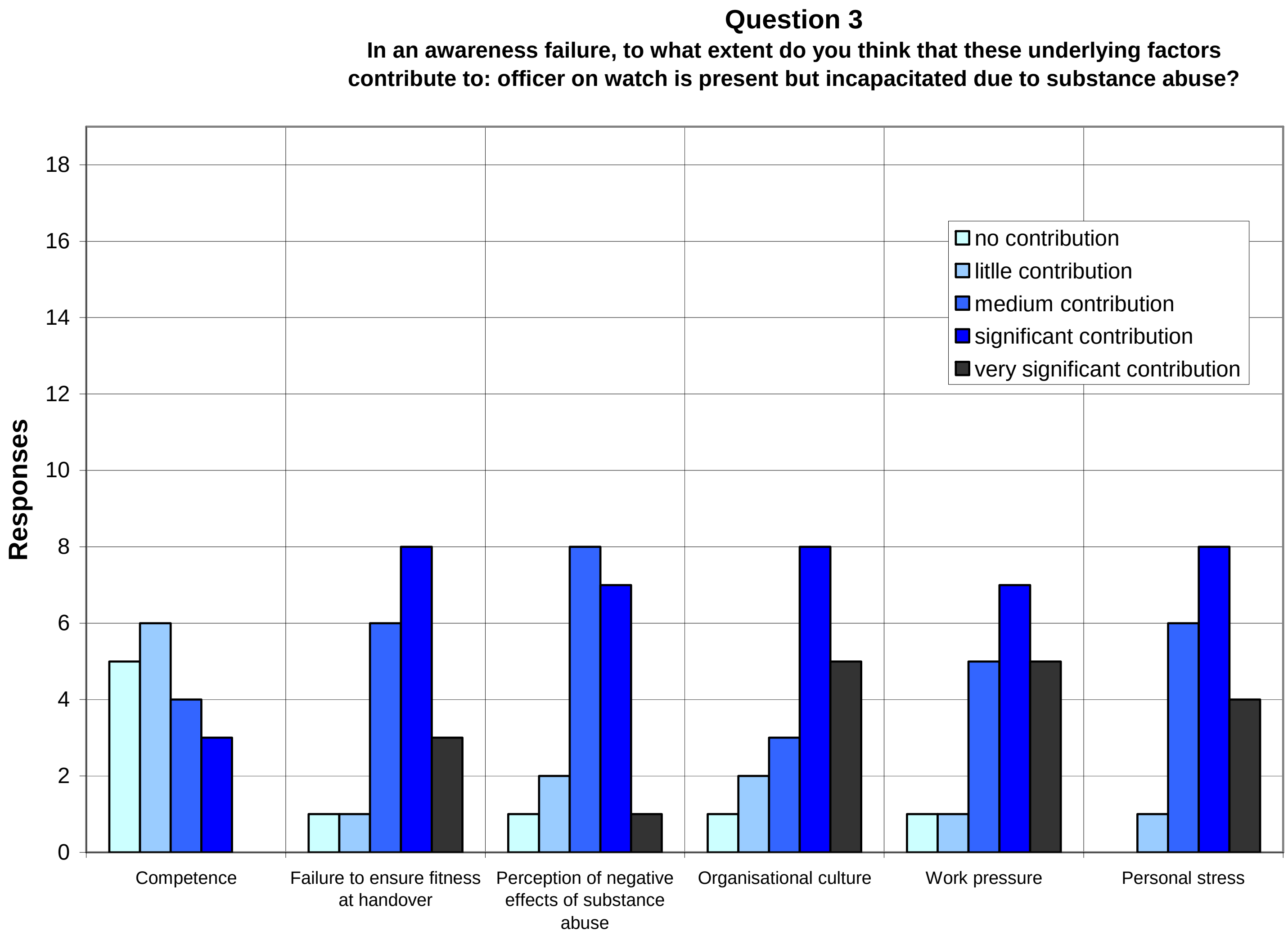
Question 1
Considering collisions between ships and offshore installations, to what extent do you think that the following scenarios contribute?

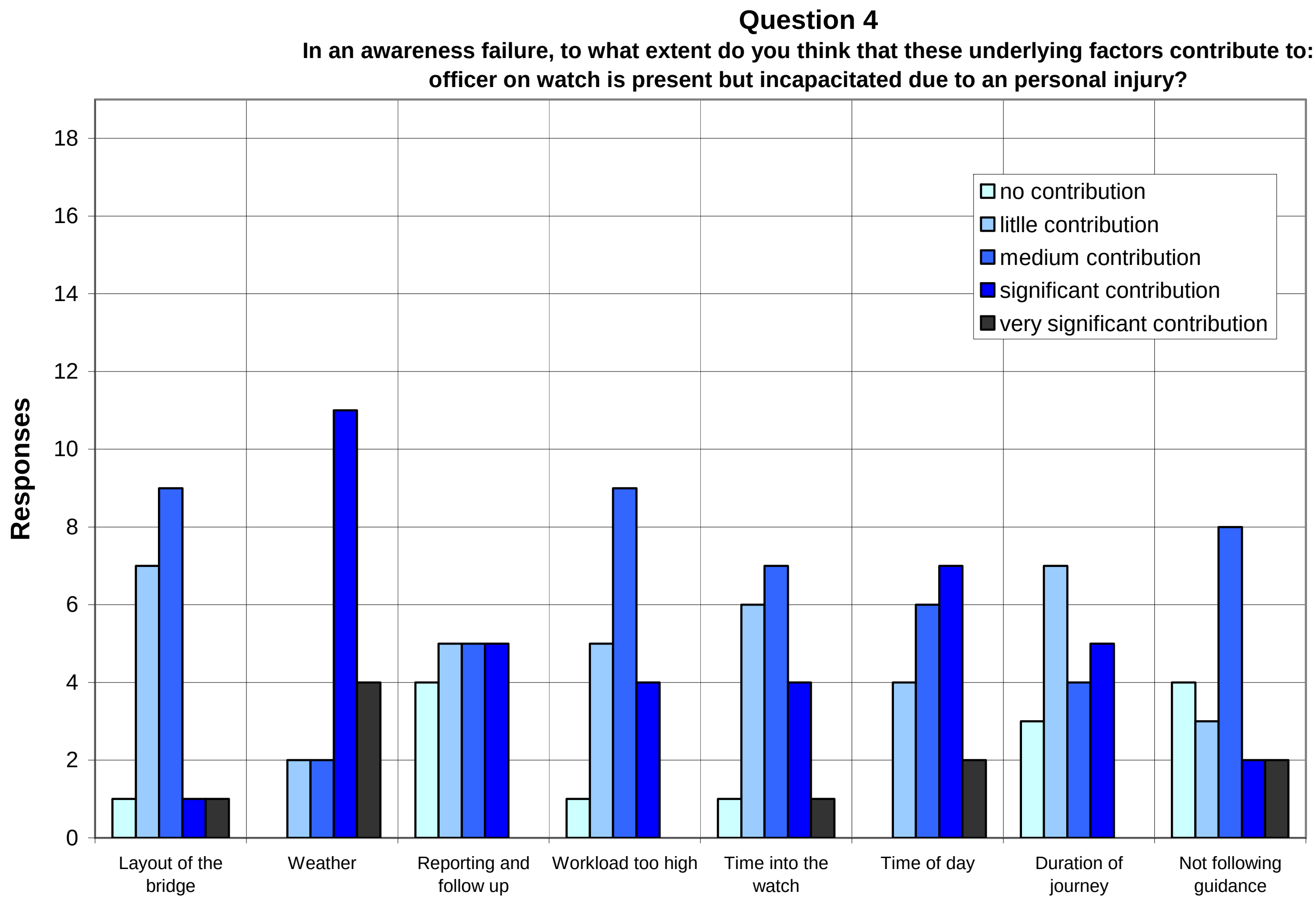


Question 2

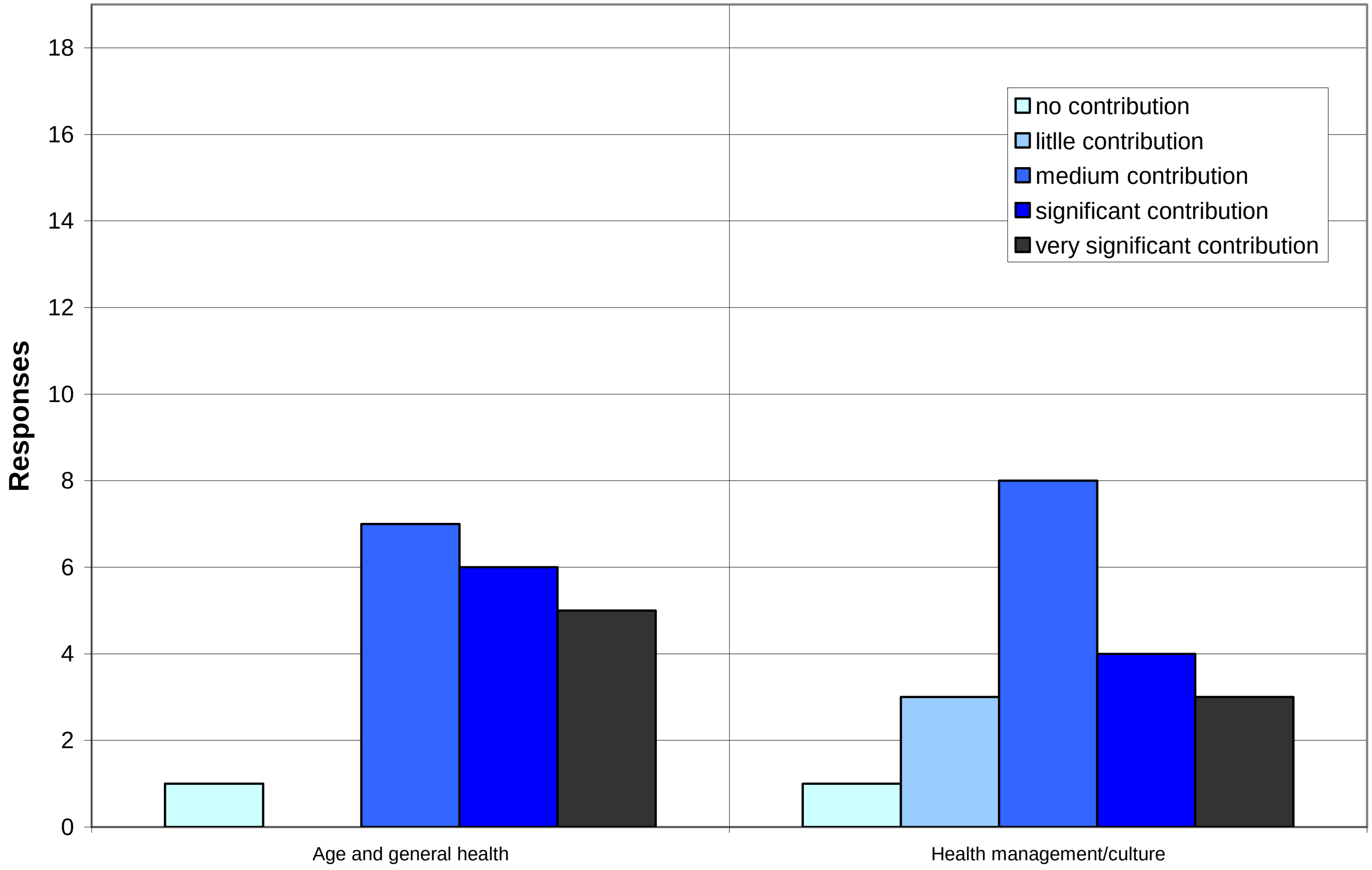
Considering collisions, to what extent do you think the following causes contribute to lack of awareness on ship?



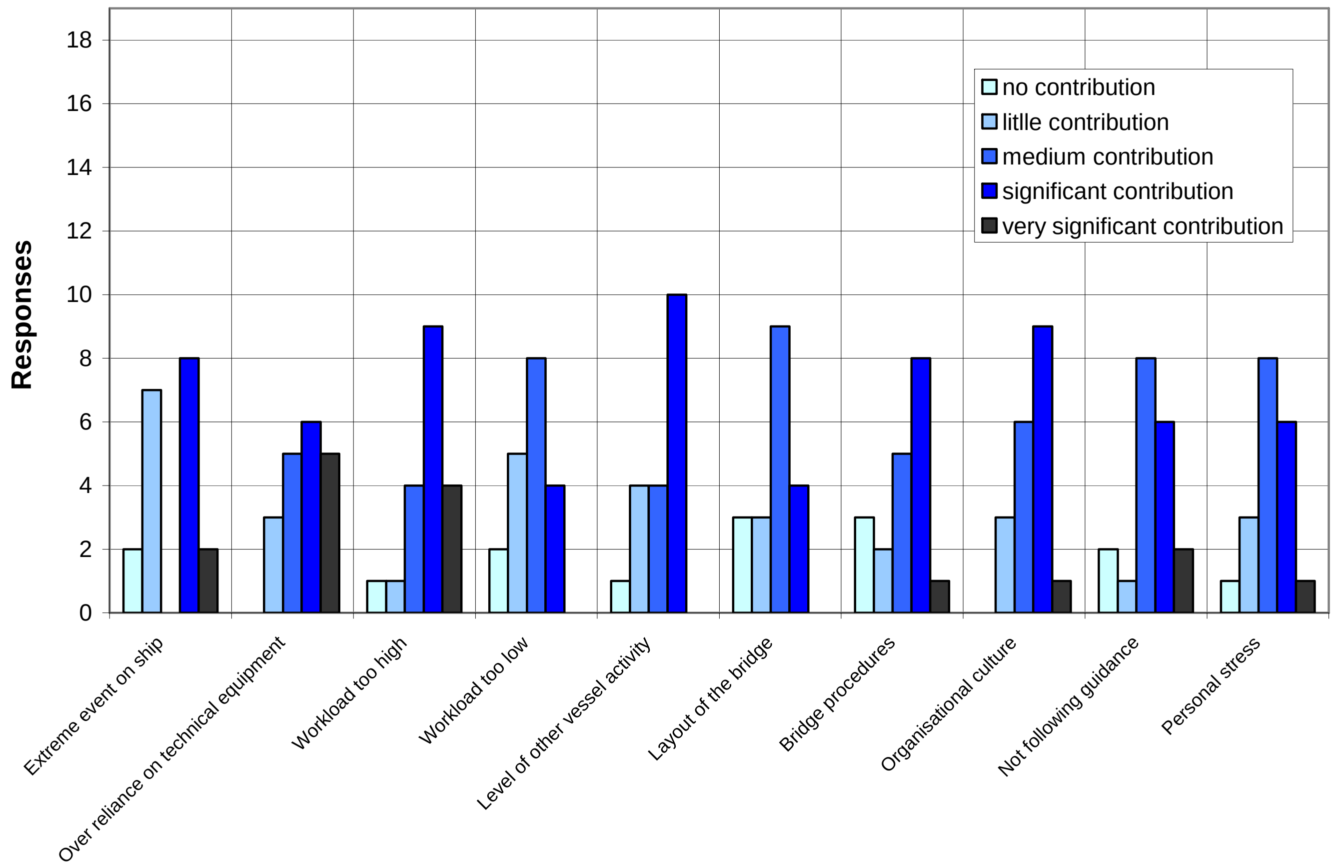

Question 3
In an awareness failure, to what extent do you think that these underlying factors contribute to: officer on watch is present but incapacitated due to substance abuse?
Responses
0
2
4
6
8
10
12
14
16
18
no contribution
litlle contribution
medium contribution
significant contribution
very significant contribution
Competence
Failure to ensure fitness at handover
Perception of negative effects of substance abuse
Organisational culture
Work pressure
Personal stress

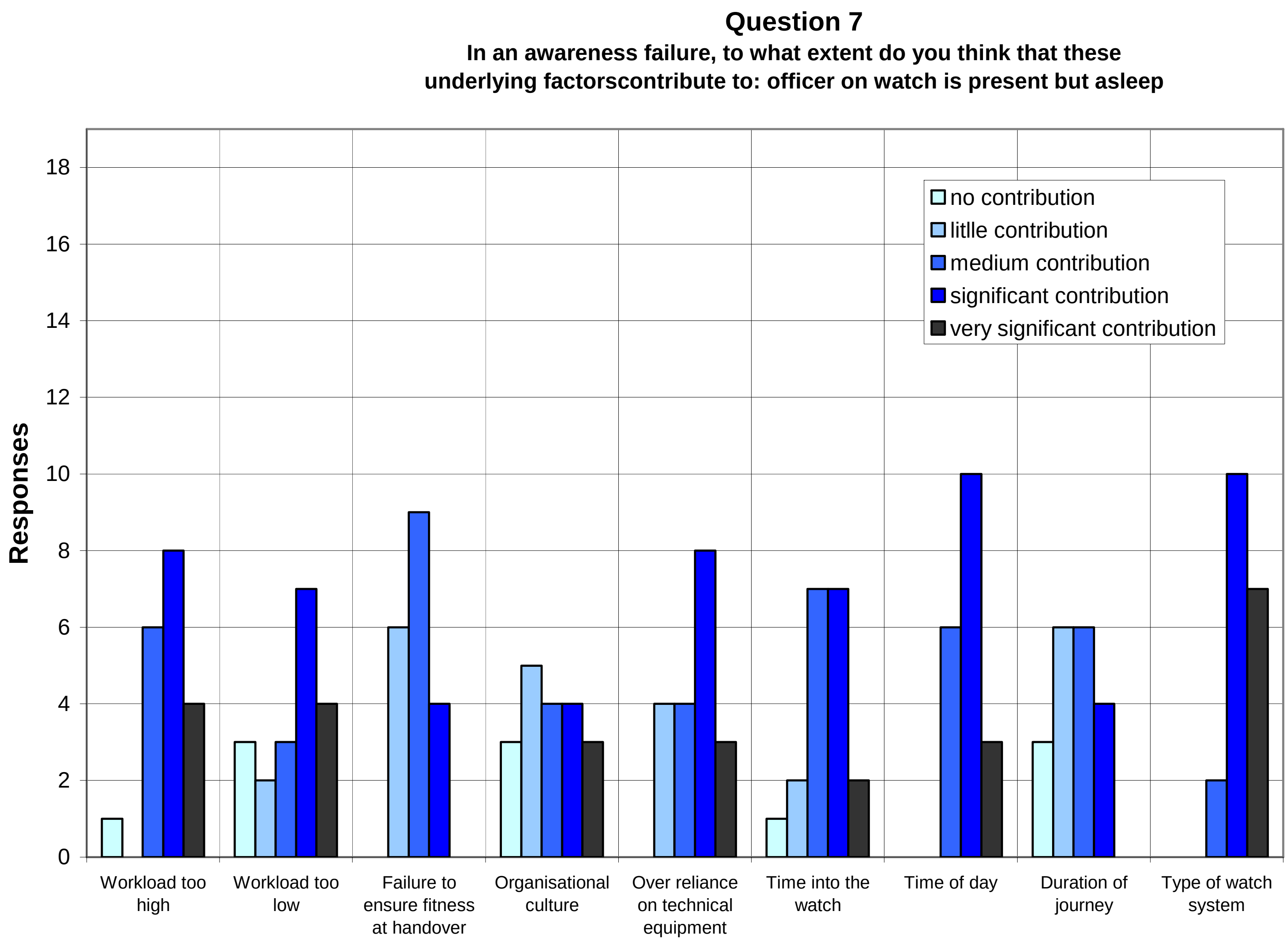

Question 4
In an awareness failure, to what extent do you think that these underlying factors contribute to:
officer on watch is present but incapacitated due to an personal injury?
Responses
0
2
4
6
8
10
12
14
16
18
no contribution
litlle contribution
medium contribution
significant contribution
very significant contribution
Layout of the bridge
Weather
Reporting and follow up
Workload too high
Time into the watch
Time of day
Duration of journey
Not following guidance

Question 5
In an awareness failure, to what extent do you think that these underlying factors contribute to: officer on watch is present but incapacitated due to illness

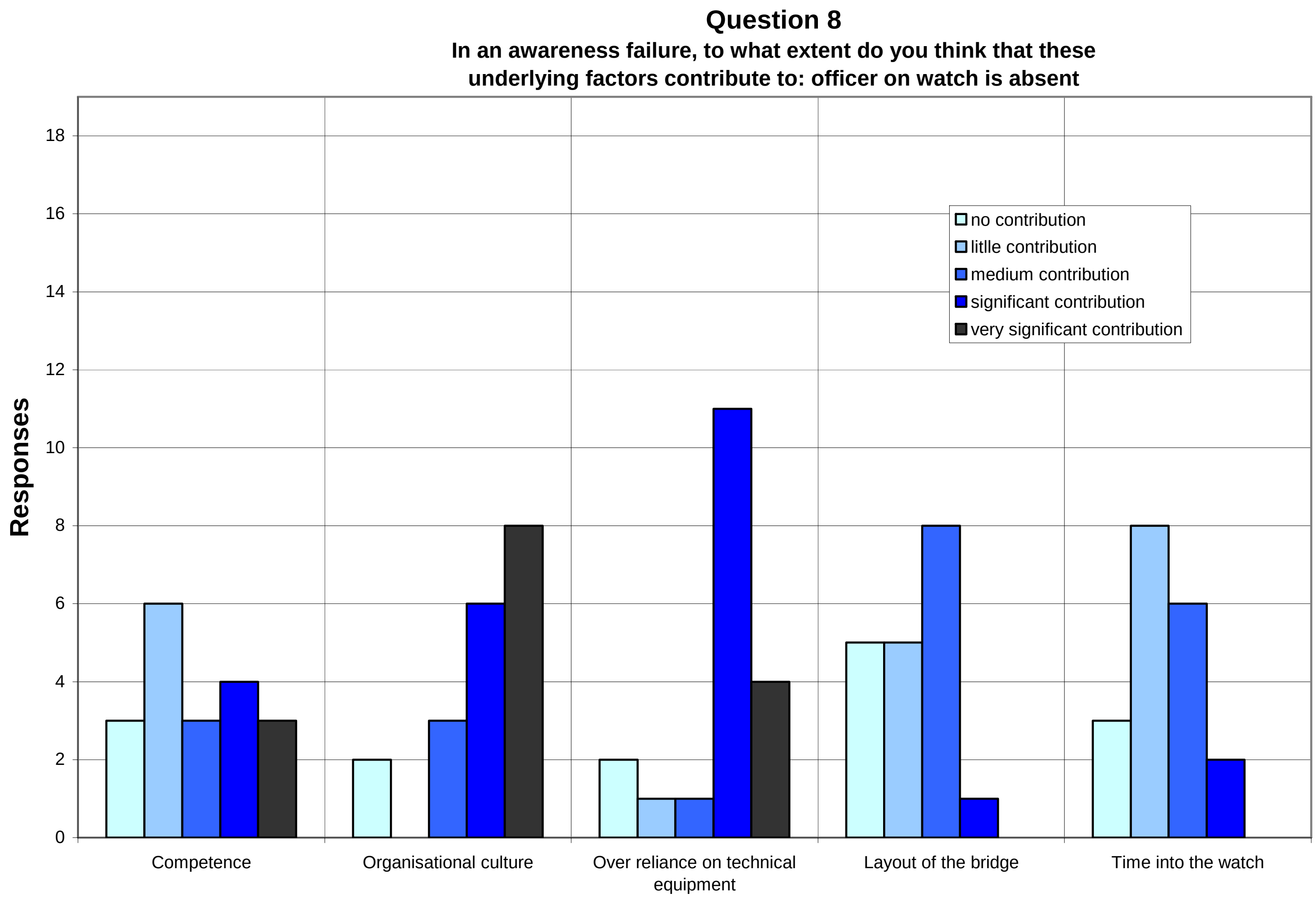


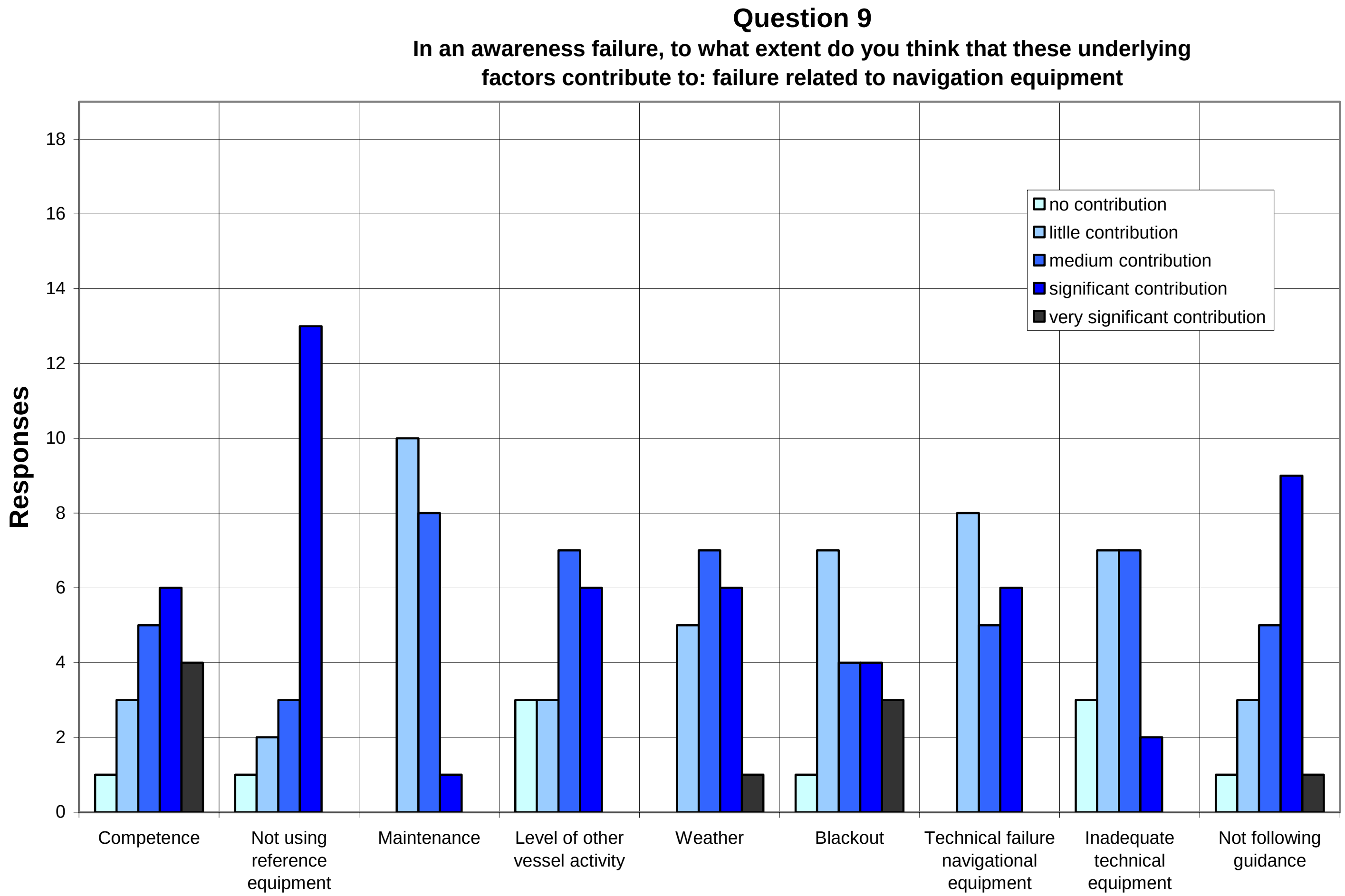
Question 6
In an awareness failure, to what extent do you think that these underlying factors contribute to: officer on watch is present but distracted



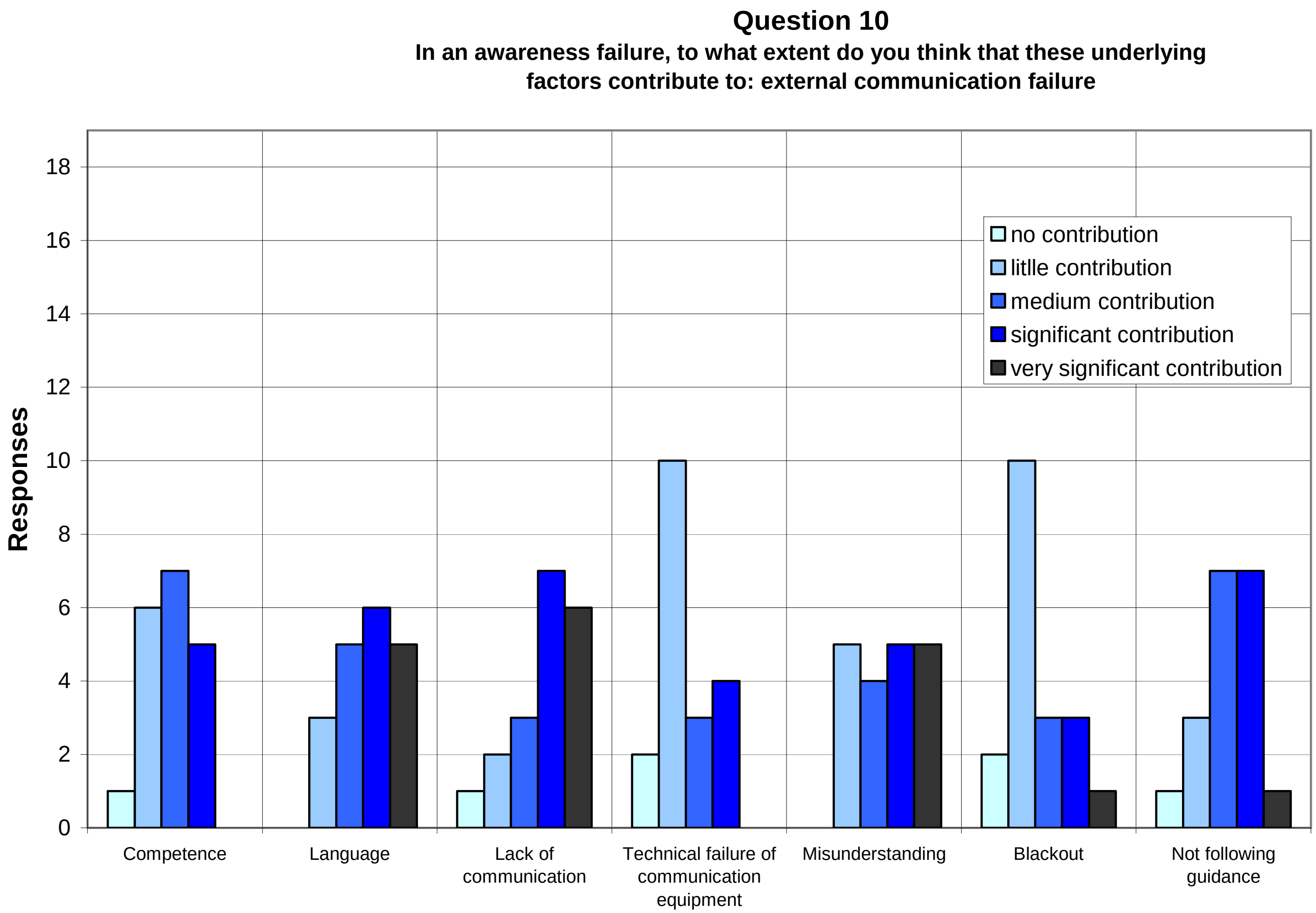


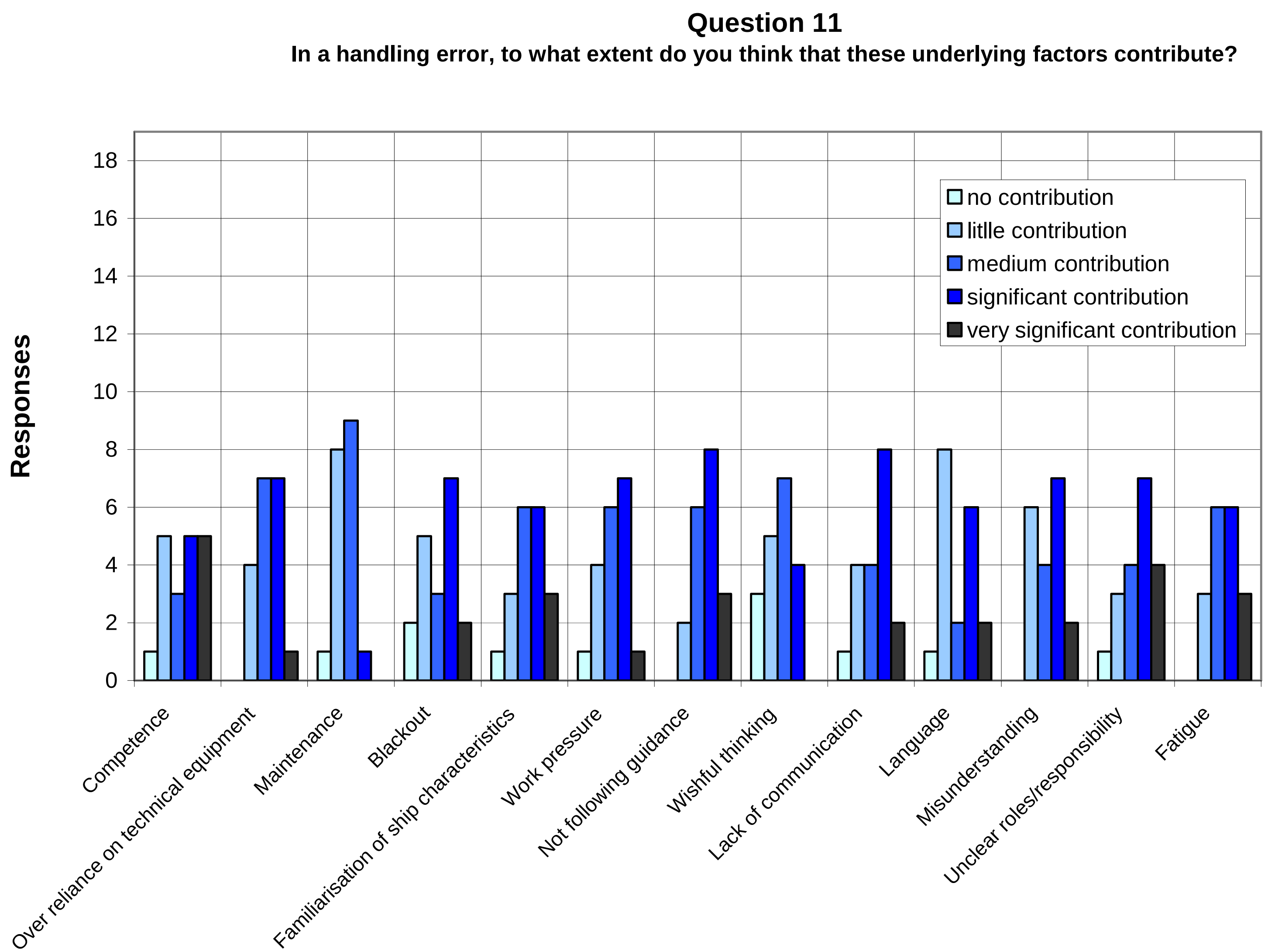
Question 7
In an awareness failure, to what extent do you think that these
underlying factorscontribute to: officer on watch is present but asleep
Responses
0
2
4
6
8
10
12
14
16
18
no contribution
litlle contribution
medium contribution
significant contribution
very significant contribution
Workload too high
Workload too low
Failure to ensure fitness at handover
Organisational culture
Over reliance on technical equipment
Time into the watch
Time of day
Duration of journey
Type of watch system


Question 8
In an awareness failure, to what extent do you think that these underlying factors contribute to: officer on watch is absent
Responses
0
2
4
6
8
10
12
14
16
18
no contribution
litlle contribution
medium contribution
significant contribution
very significant contribution
Competence
Organisational culture
Over reliance on technical equipment
Layout of the bridge
Time into the watch



Question 9
In an awareness failure, to what extent do you think that these underlying factors contribute to: failure related to navigation equipment
Responses
0
2
4
6
8
10
12
14
16
18
no contribution
litlle contribution
medium contribution
significant contribution
very significant contribution
Competence
Not using reference equipment
Maintenance
Level of other vessel activity
Weather
Blackout
Technical failure navigational equipment
Inadequate technical equipment
Not following guidance

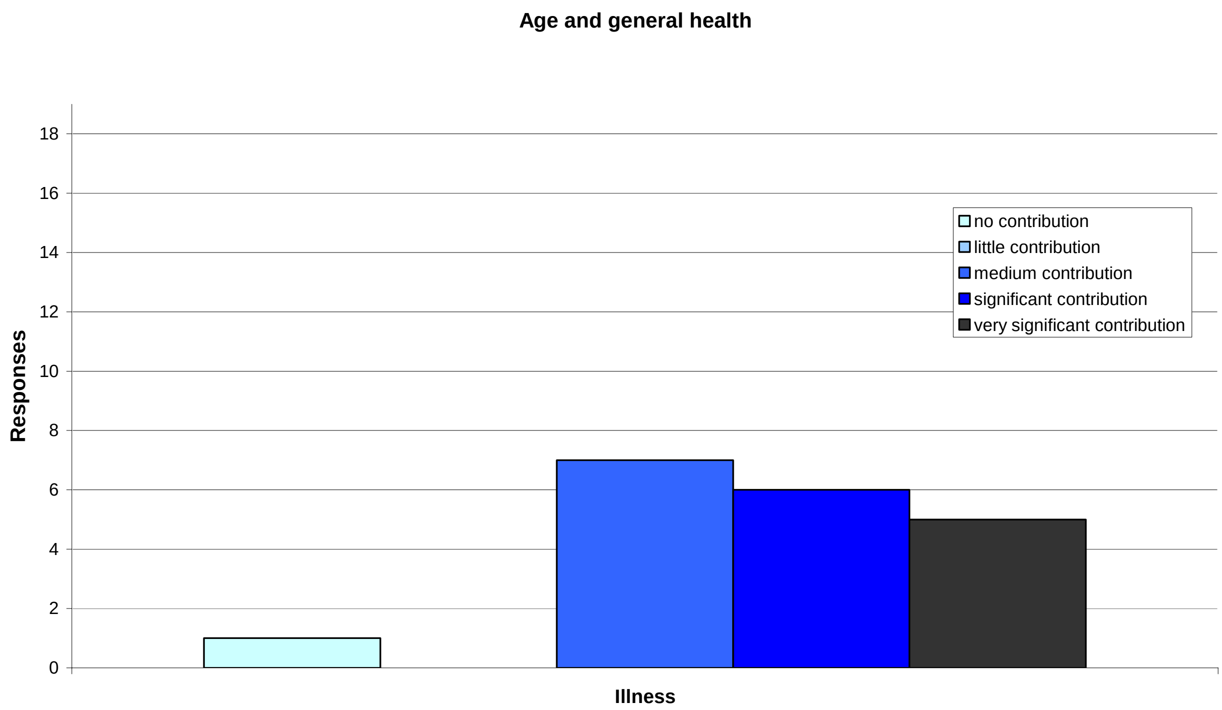

Question 10
In an awareness failure, to what extent do you think that these underlying factors contribute to: external communication failure
Responses
0
2
4
6
8
10
12
14
16
18
no contribution
litlle contribution
medium contribution
significant contribution
very significant contribution
Competence
Language
Lack of communication
Technical failure of communication equipment
Misunderstanding
Blackout
Not following guidance



Question 11
In a handling error, to what extent do you think that these underlying factors contribute?
Responses
18
16
14
12
10
8
6
4
2
0
no contribution
litlle contribution
medium contribution
significant contribution
very significant contribution
Competence
Over reliance on technical equipment
Maintenance
Blackout
Familiarisation of ship characteristics
Work pressure
Not following guidance
Wishful thinking
Lack of communication
Language
Misunderstanding
Unclear roles/responsibility
Fatigue

Appendix F – Results: underlying factors

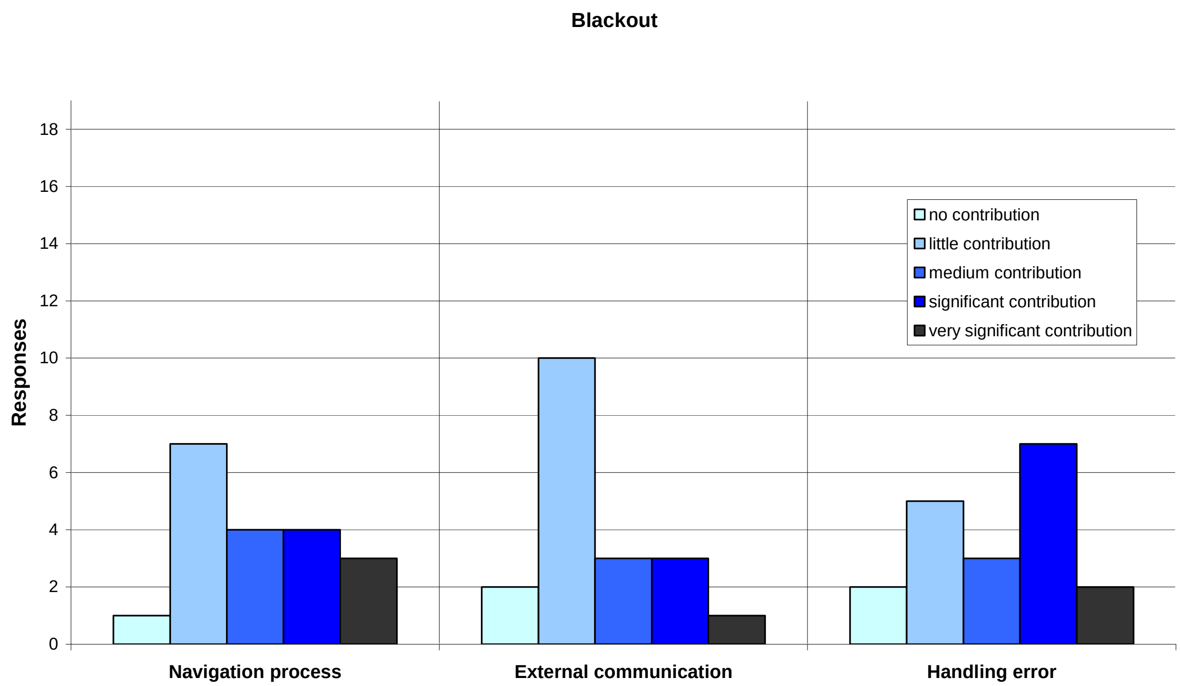
Results for the underlying factors from the interviews, presented alphabetically.



Data from literature review
There are some differences amongst operators with regards to health related attitudes and behaviours and hence somewhat varying tolerance to withstand task demands (Gretch et al, 2008). There is an absence of literature that aims to evaluate the relationship between seafarers' health and performance. 81 % failed to reach a minimum exercise levels required for good health. (Hetherington et al, 2006)

No statistics that show a relationship between age, general health and injuries or severe illnesses onboard ships have been found.

Comments during interviews
There are regular medical check-ups in the maritime industry and e.g. a requirement that crew members must not have a BMI (Body Mass Index) that exceed 25 (Emil Aall Dahle, 2008-11-11).

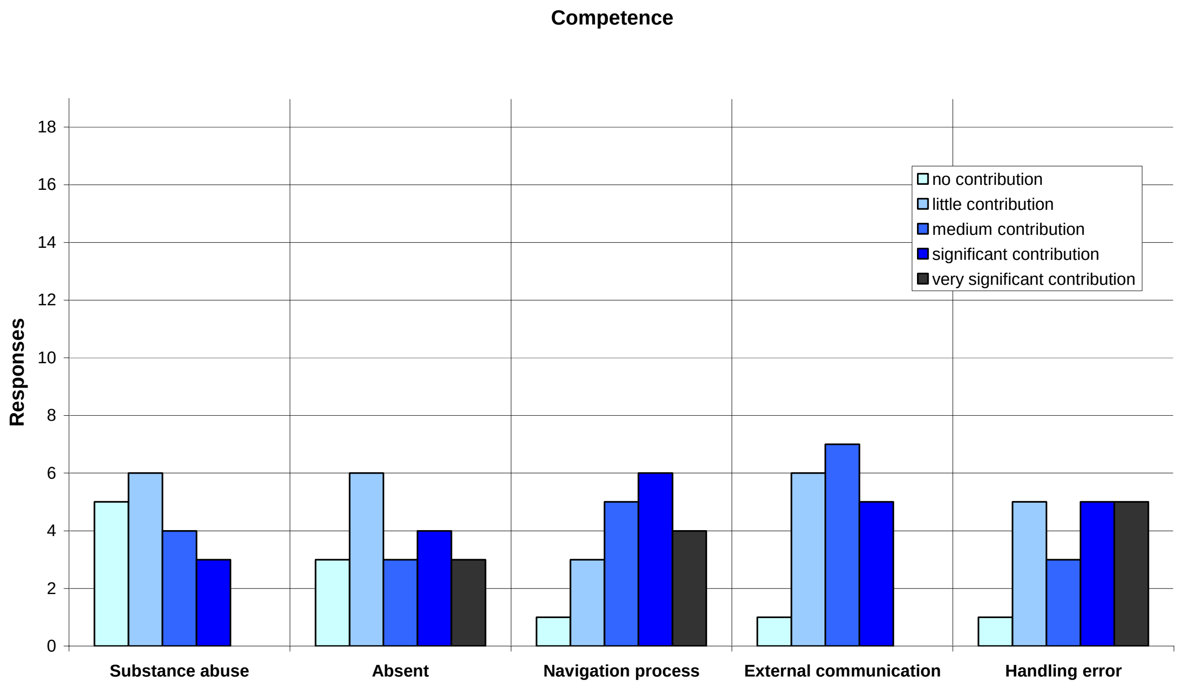


Data from literature review

It can be noted that 16 % of the near-misses 1997-2001 were related to a total power loss (HSE, 2003).

Comments during interviews

Blackout is not a probable reason for a communication failure because of redundancy and backup-systems (Tor Egil Hopen Saue, 2008-11-03; Emil All Dahle, 2008-11-11).



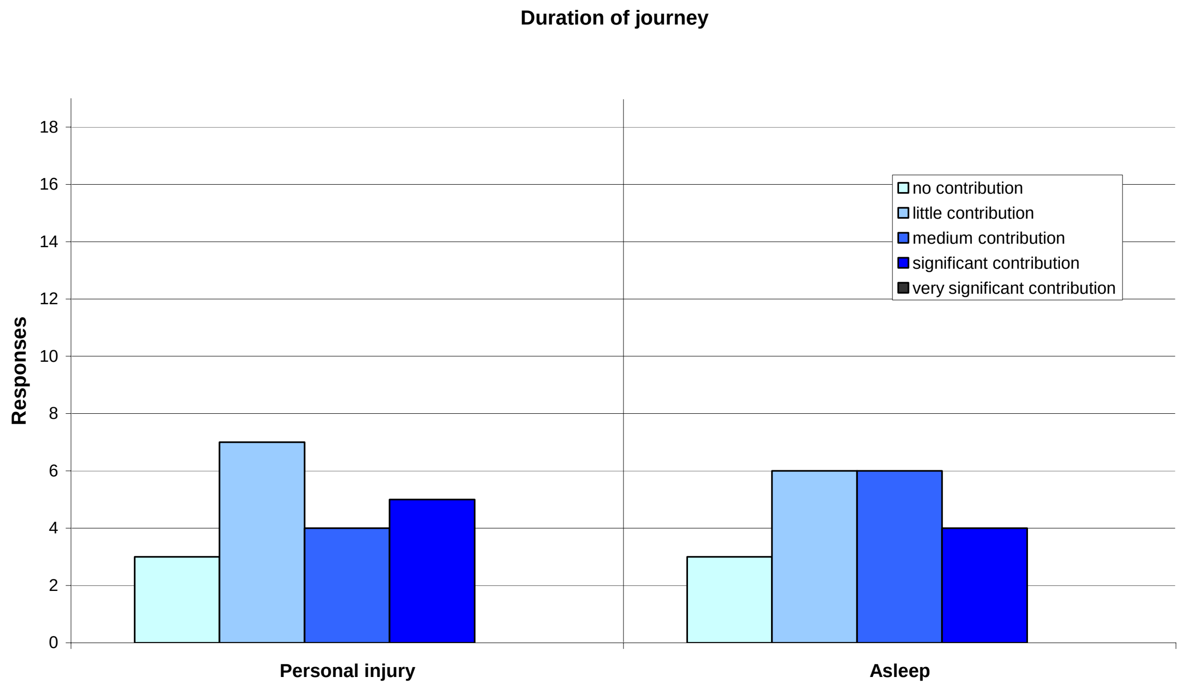
Data from literature review

Competence is an important factor in collisions between two ships and exemplified by how it contributes to almost 80 % of the accidents in statistics (MAIB, 2004). However, it is likely that this is related to collisions between two ships, considering how it would be unlikely that a vessel would enter the safety zone of an installation and approach a platform due to lack of competence.

Lack of skill and lack of knowledge are two of the most contributing factors to losses in shipping companies, with a moderate to high contribution for about 60 % of the companies (Alvik, 2000). Wang & Zhang (2000) mention lack of knowledge and experience as two leading causes of human error.

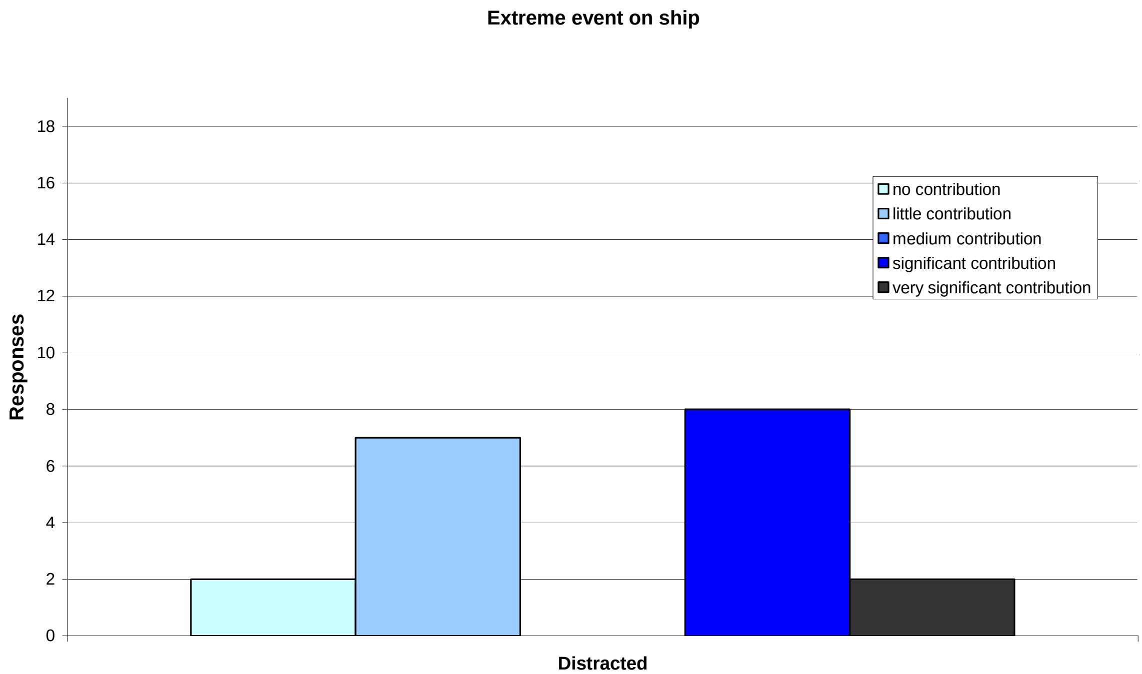
Comments during interviews

-



Data from literature review
There are few indicators found in literature that imply that the duration of a journey has an impact on collisions. It does however appear like fatigue is related to duration of voyage, considering that most accidents caused by fatigue occur during the first week of a journey (Smith, 2001).

Comments during interviews
A long voyage contributes to more routines and less interruptions which lead to better performance (Carl-Henrik Wulff, 2008-11-10).

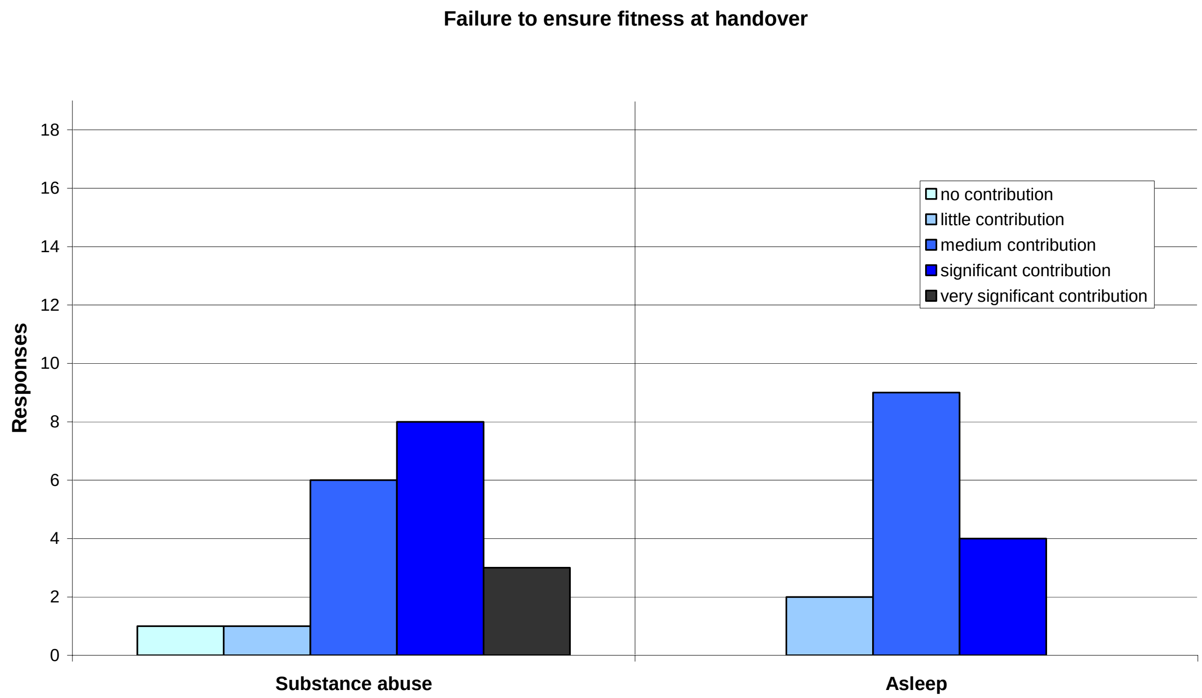


Data from literature review

-

Comments during interviews

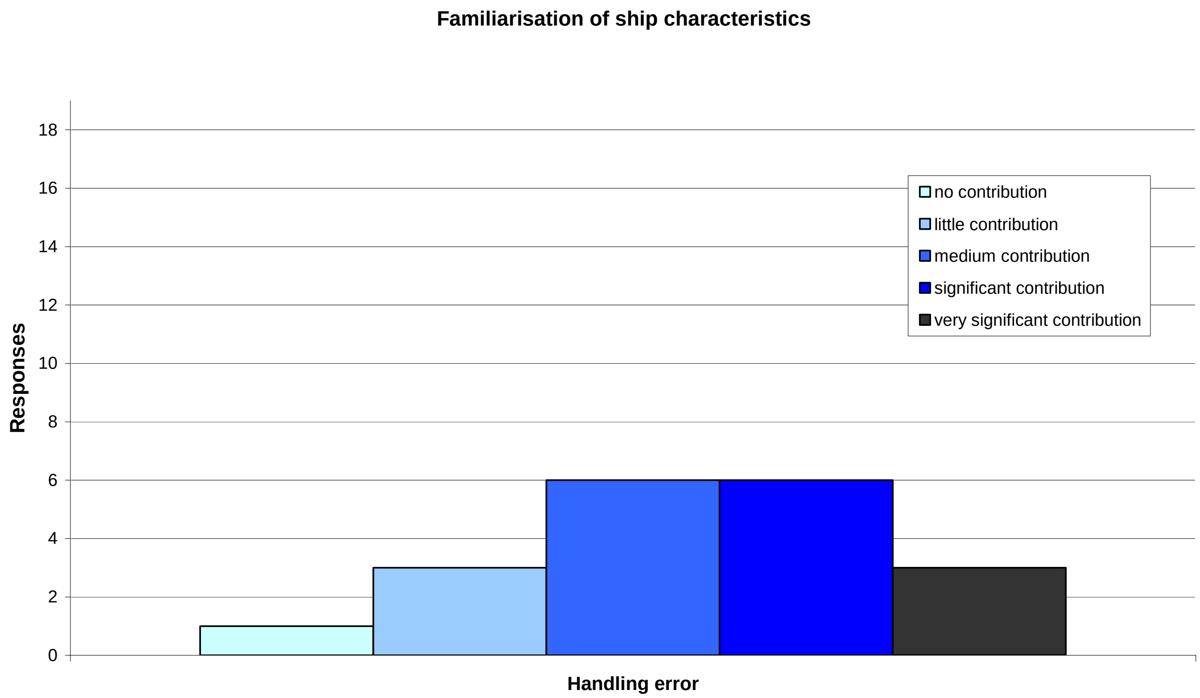
Some respondents probably considered how unlikely it is that an extreme event would take place when the vessel is close to an installation, while others did not have this in mind, which resulted in widely spread results. As commented during an interview "If an extreme event happens on the ship, you usually stop the vessel and otherwise somebody else would take care of things so that you wouldn't need to be distracted" (Jens-Uwe Schröder, 2008-11-13).



Data from literature review
Failure with regards to the watch handoff is identified in 5 of 109 accident reports from the Australian Transportation Safety Bureau (Baker & McCaffrey, 2005). Handover briefings are an essential component of teamwork and cooperation (TSB, 1998).

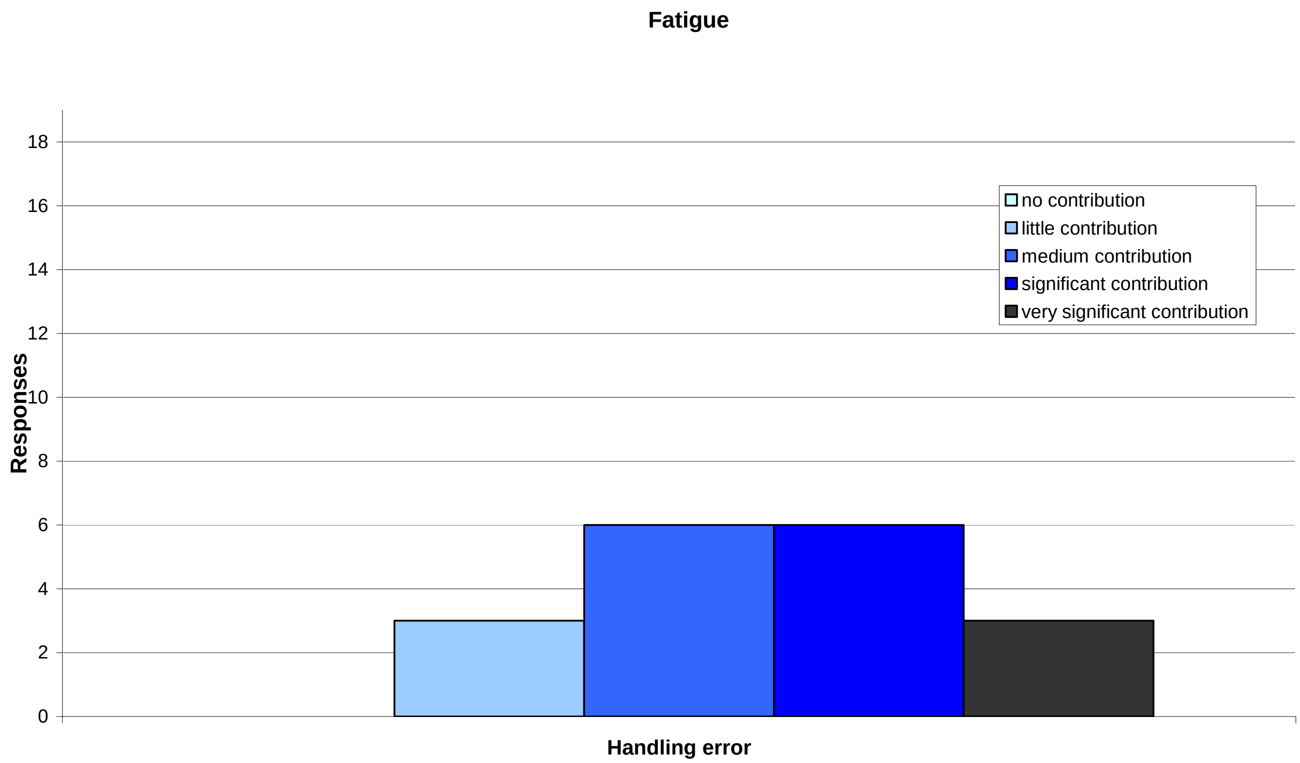
Comments during interviews

-



Data from literature review
A lack of ship-specific knowledge is cited as a problem by 78% of mariners surveyed (National Research Council, 1990).

Comments during interviews
It is likely that this factor is of more importance in scenarios with collision between two ships-, taking into account that the features of vessels are not so different that this would result in unsuccessful collision avoidance. This view is shared by e.g. Arve Lerstad (2008-11-04) who stated that no deeper understanding is necessary to change course of a vessel to avoid a collision with an offshore installation.



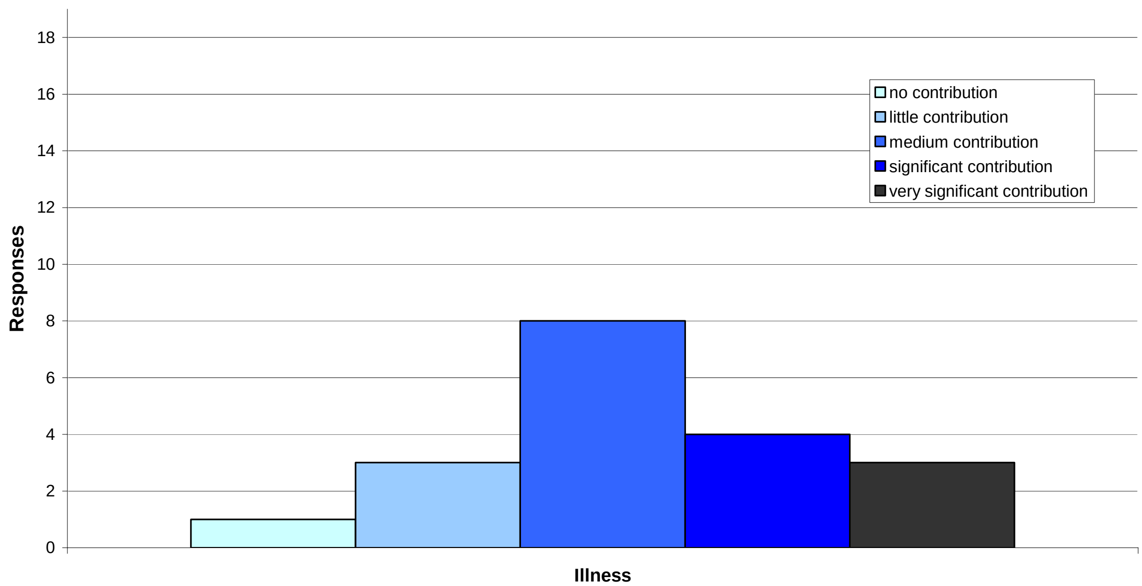
Data from literature review

The influence of fatigue in personal injuries varies, from being a factor of 3% to 16% in statistics (McCallum et al, 1996). Fatigue is however a major concern for seafarers, an opinion shared by 64% of the members of the Nautical Institute which includes 7000 people from 110 countries (Seaways, 2006). Sleep/fatigue is difficult to measure which leads to an underestimation in accident reports (Swedish Maritime Administration, 2008). Operator fatigue is often problematic or impossible to identify following an accident (Gerch et al, 2008).

Comments during interviews

A point of view from a respondent was that more risky decisions are made when a person is fatigued, such as the choice to leave the bridge (Jens-Uwe Schröder, 2008-11-13).

Health management/culture within the organisation

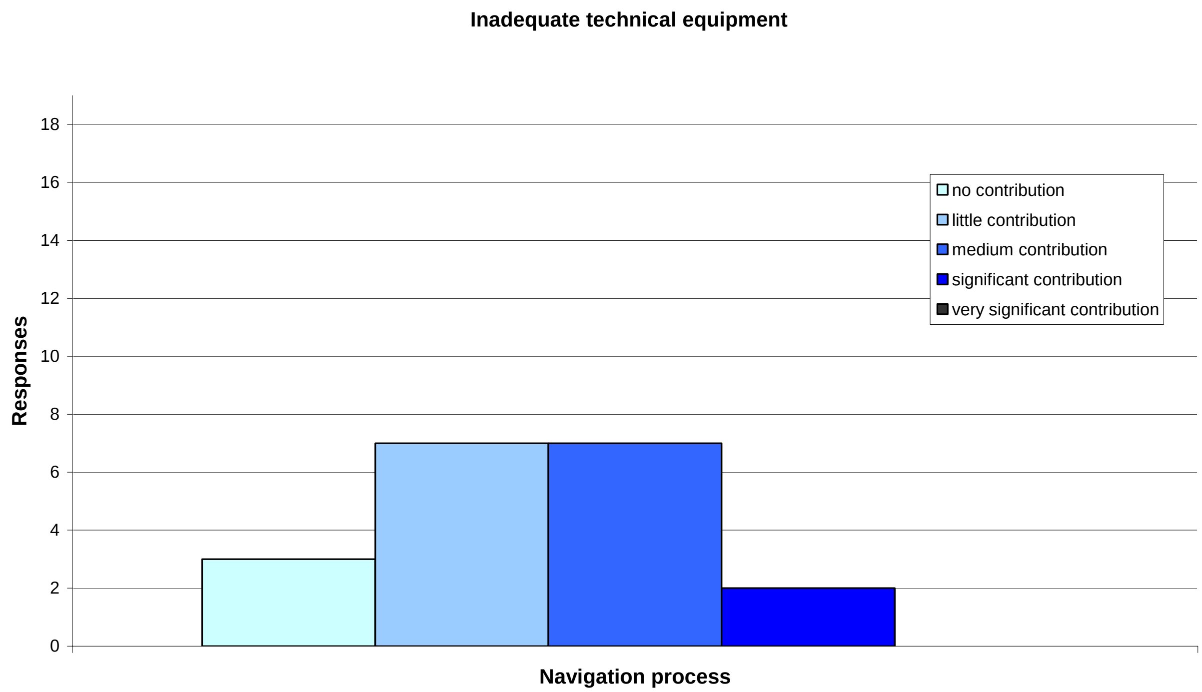


Data from literature review

According to Lang (2000), the manning level is often minimal why every single person is important for the operation of a ship and a seafarer is more or less expected to perform his/hers duties whether they are fully fit or not. Research from other domains such as the offshore oil industry indicates a positive relationship between health management and safety performance (Hetherington et al, 2006).

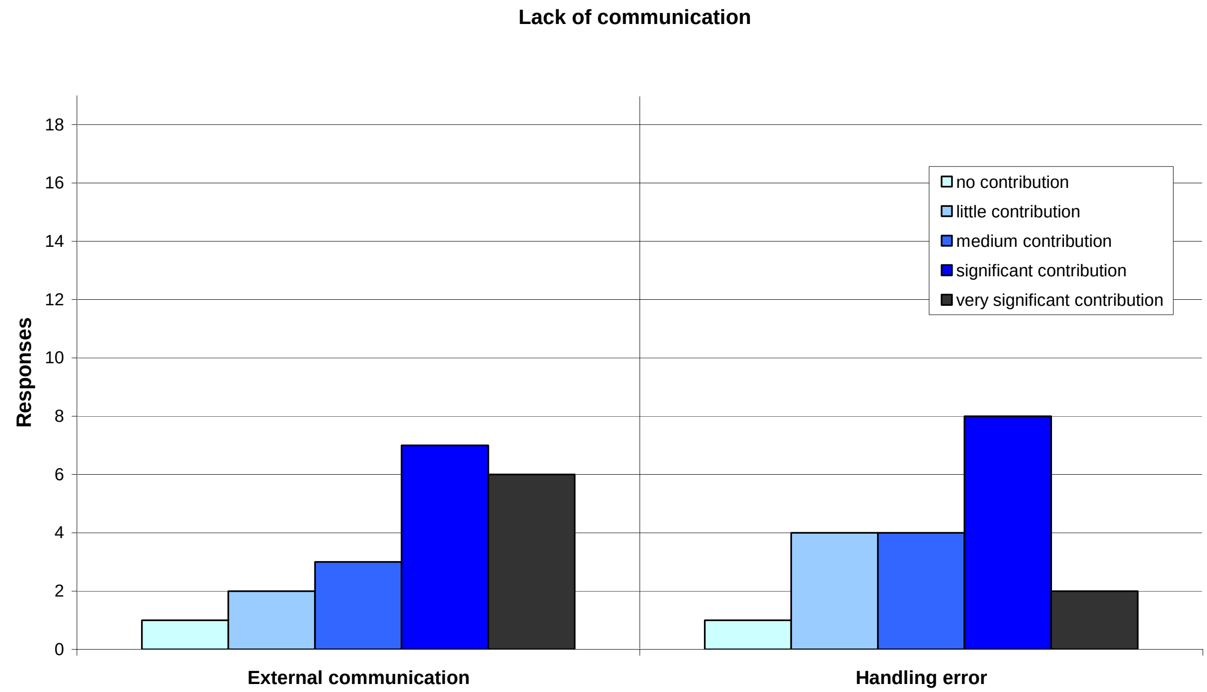
Comments during interviews

It was mentioned during an interview that "you will probably be on your watch even if you are ill, because of inflexible systems" (Stefan Lindberg, 2008-11-14).



Data from literature review
A study made by Alvik (2000) that measure safety management within shipping companies shows that inadequate tools or equipment have contributed little to the losses related to ship accidents within companies. In research by Kristiansen & Soma (1999), less than adequate bridge equipment is believed to cause 4 % of all situations where there is a loss of navigational control.

Comments during interviews
An opinion during an interview was that there should be an adequate level of technical equipment, due to frequent inspections of ships (Carl-Henrik Wulff, 2008-11-10).

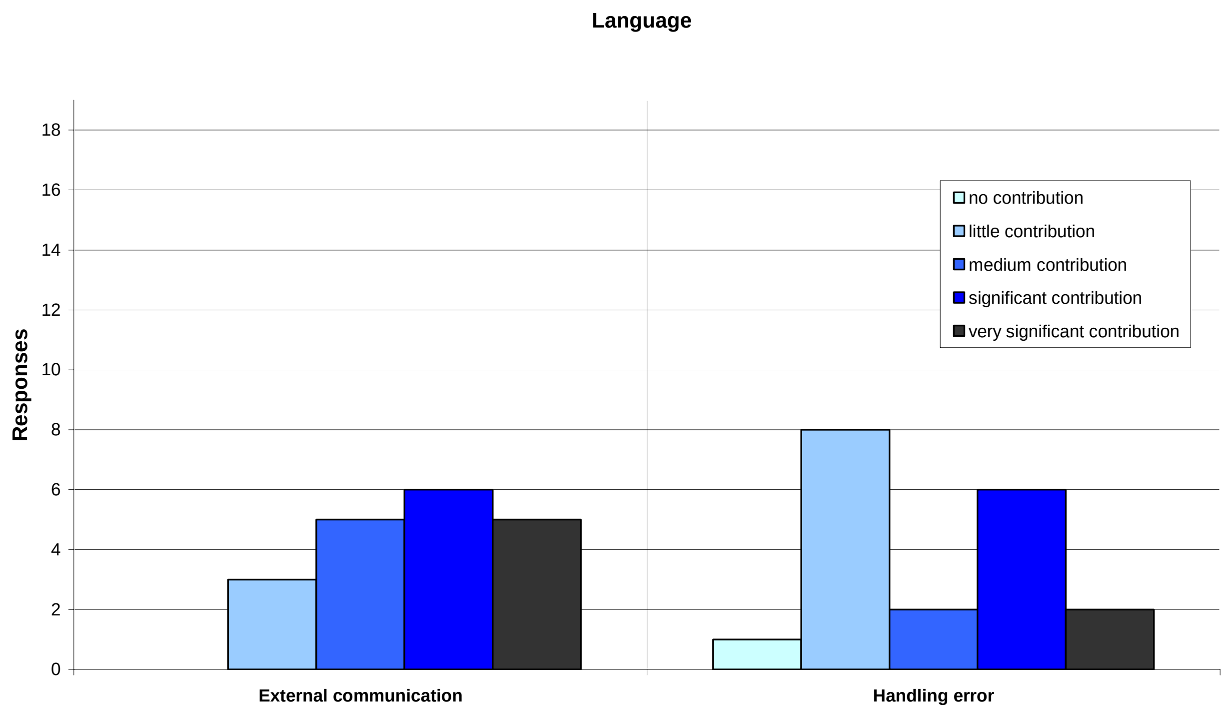


Data from literature review

47 of 273 accidents (i.e. 17%) caused by human errors were related to lack of communication according to research about accident causation. A review of accidents in Canadian waters between 1981 and 1992 states that there are differences in perceptions between masters and pilots regarding the need for exchange of info and the adequacy of the information being exchanged. (TSB, 1998)

Comments during interviews

-

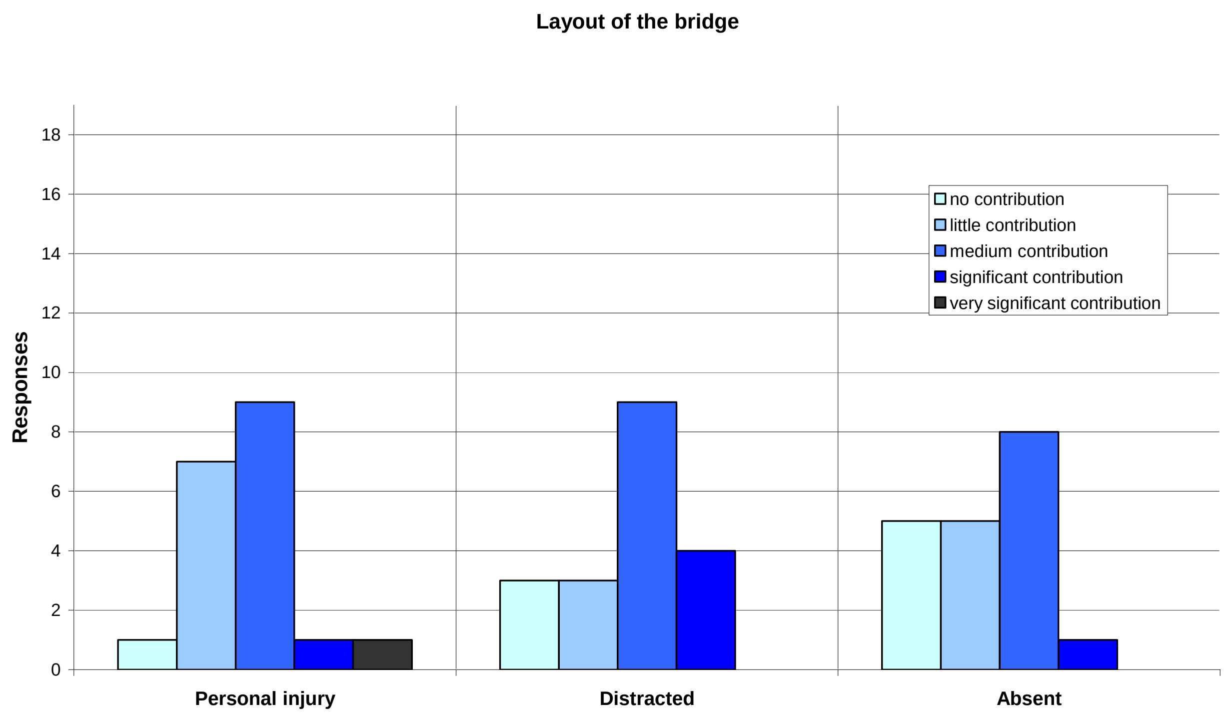


Data from literature review

Several studies concern language and communication problems related to language discrepancies. Hetherington et al. (2006) conclude that only one third of all ships have single nationality crew, which potentially may create language issues. It is also noted how 20% of all pilots mean that language barriers often make it difficult to communicate (TSB, 1998). Atwell et al. (1996) have reviewed language problems in ship to ship situations when using VHF. Of 300 active mariners, 22 % answered that they always experience language problems, 19 % often and 27 % never.

Comments during interviews

-



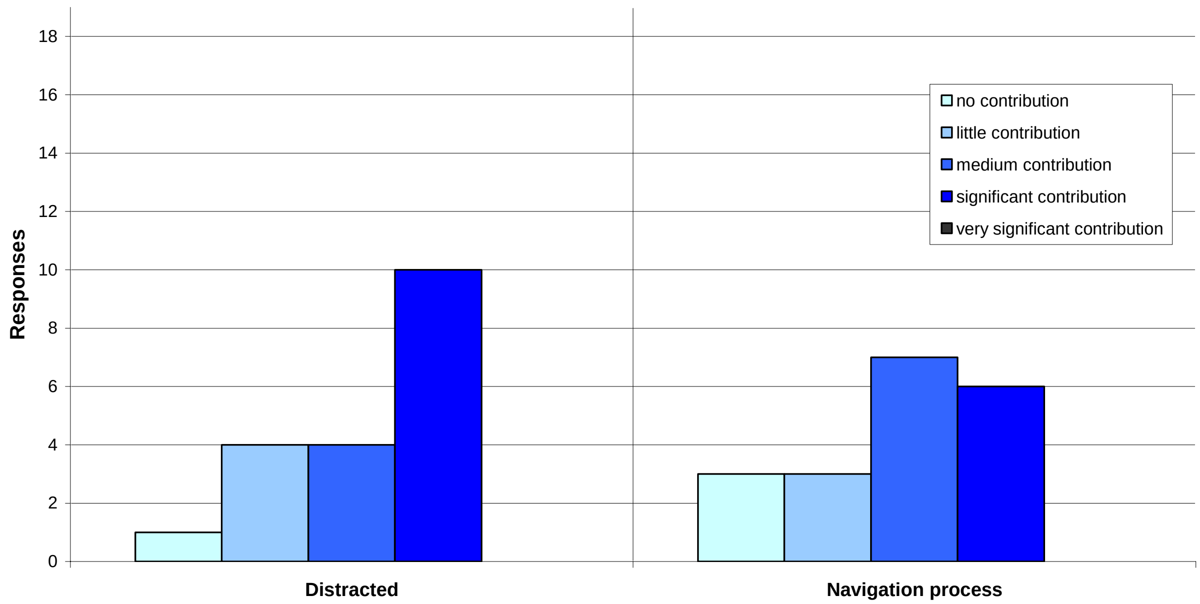
Data from literature review

An example of problems related to layout can be found in an accident report (Swedish maritime administration, 2008) where the officer on watch was unable to look out from the navigation patch. Design of vessels is commonly based on European or North American design standards and data, while many seafarers currently come from South-east Asia, which could cause a hazard due to differences in anthropometrics (McCafferty & McSweeney, 2003).

Comments during interviews

Layout is probably more important for ships with special functions than for merchant ships (Arve Lerstad, 2008-11-04).

Level of other vessel activity

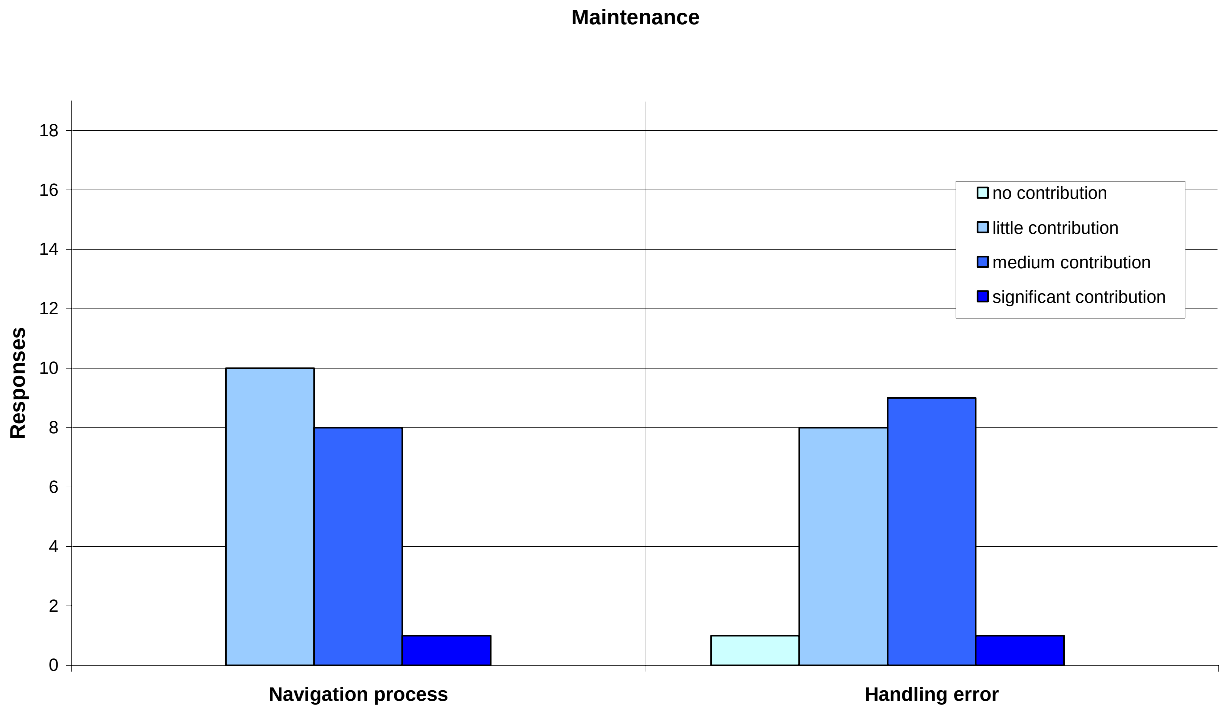


Data from literature review

It is shown in a review of accidents in Canadian waters (TSB, 1998) that 9 out of 273 accidents were related to other vessels (3%).

Comments during interviews

-

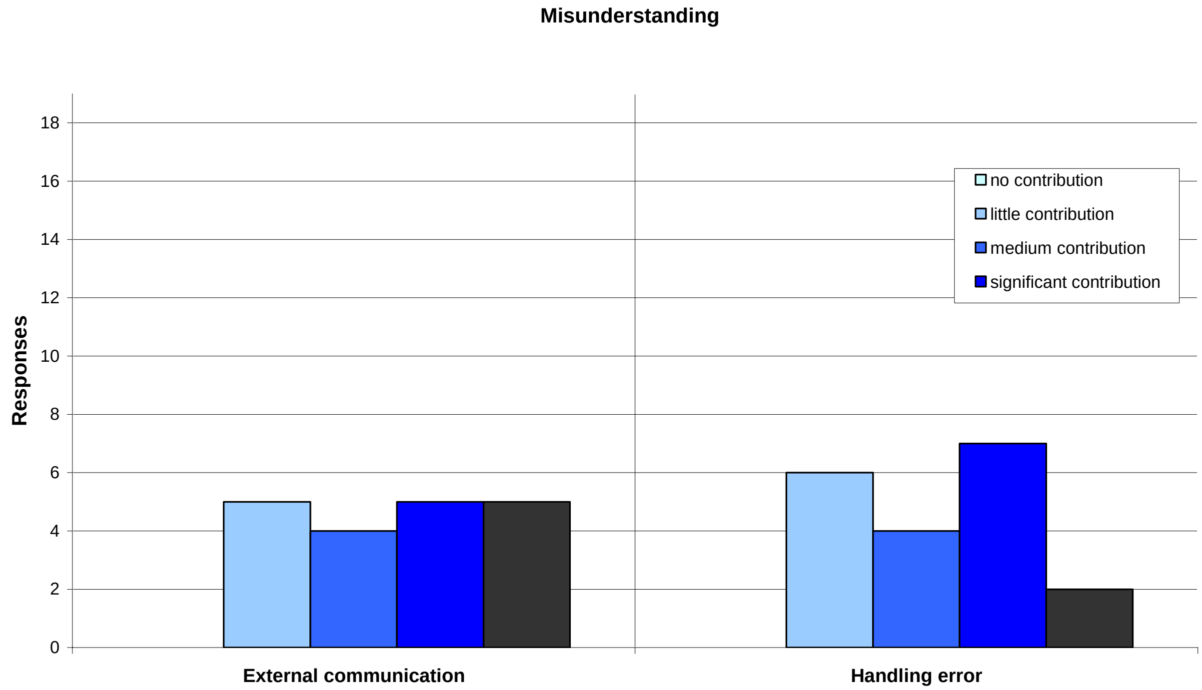


Data from literature review

Maintenance related human errors are the casual reason in 1-6 % of accidents reported to ATSB, TSB and MAIB (Baker & McCafferty, 2005). Poor maintenance of ships can lead to dangerous work environments, lack of working backup systems and crew fatigue from the need to make emergency repairs (Bryant, 1991; National Research Council, 1990; US Coast Guard, 1995).

Comments during interviews

It is common that service of technical equipment is not performed because of delays in delivers etc (Stefan Lindberg, 2008-11-14).

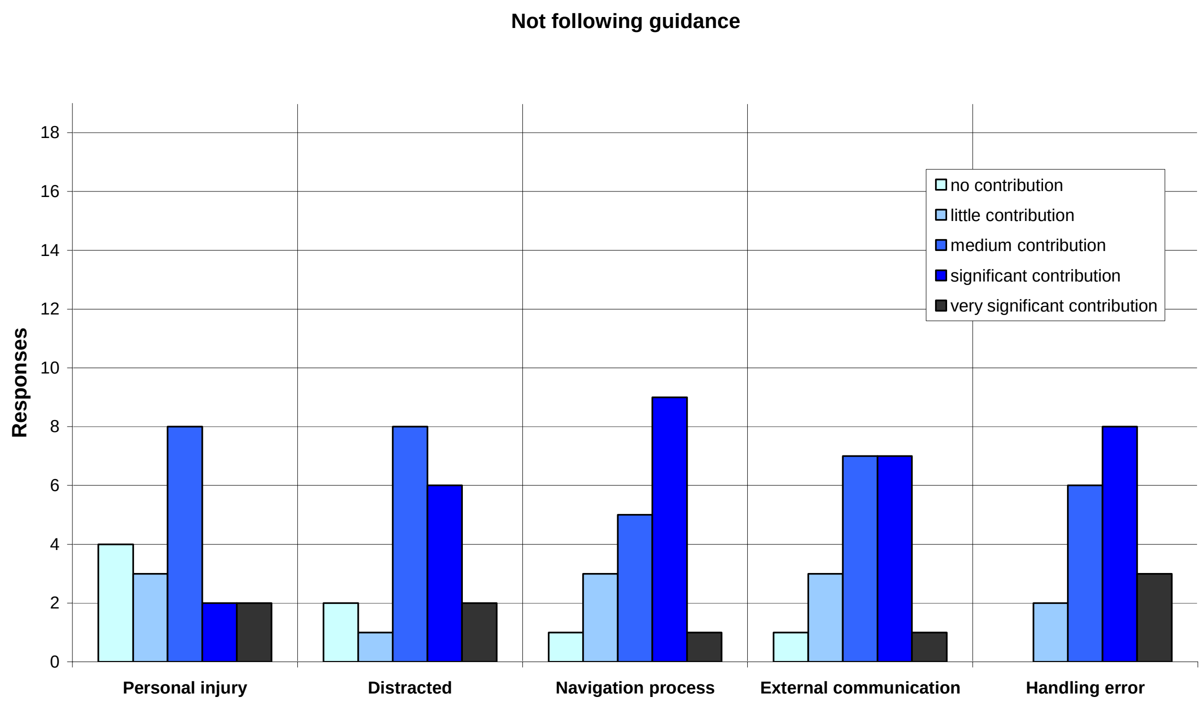


Data from literature review

Several studies show that accidents occur due to misunderstandings (TSB, 1998).

Comments during interviews

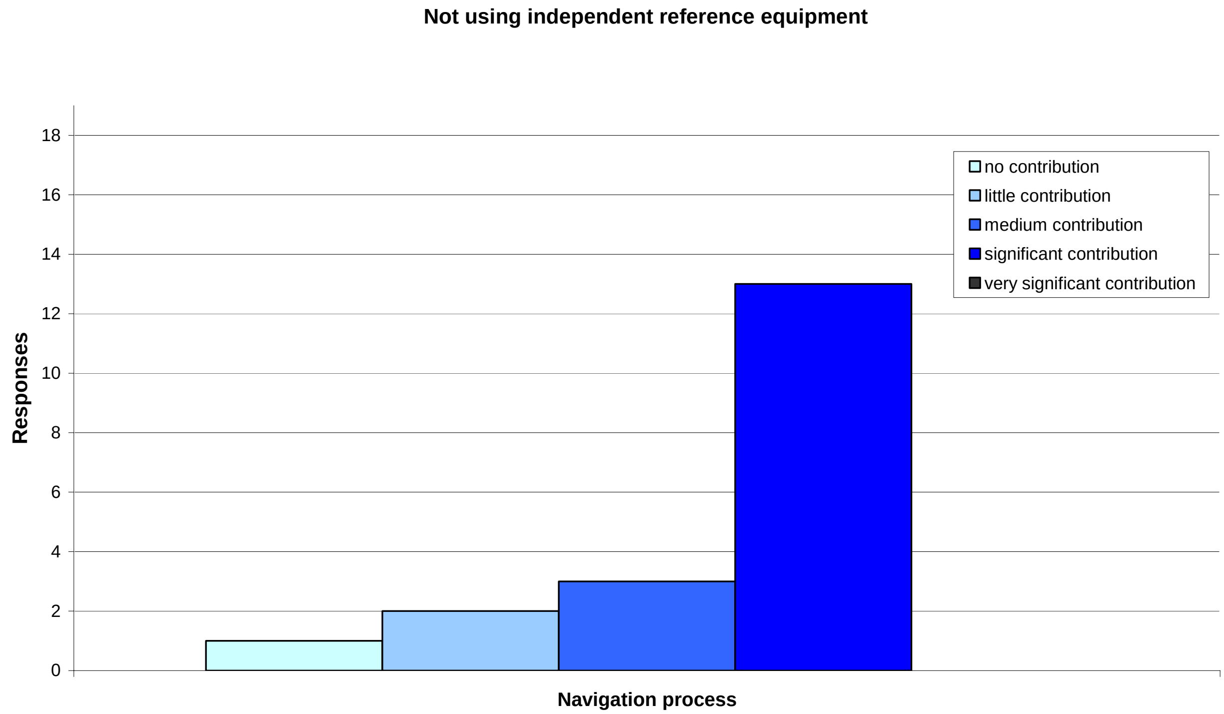
-



Data from literature review
Failures related to not following guidance are not mentioned in literature, but omission is however discussed. An incident review performed by the American Bureau of Shipping states that 6-15% of accidents are related to omissions (Baker & McCafferty, 2005).

Comments during interviews

-



Data from literature review

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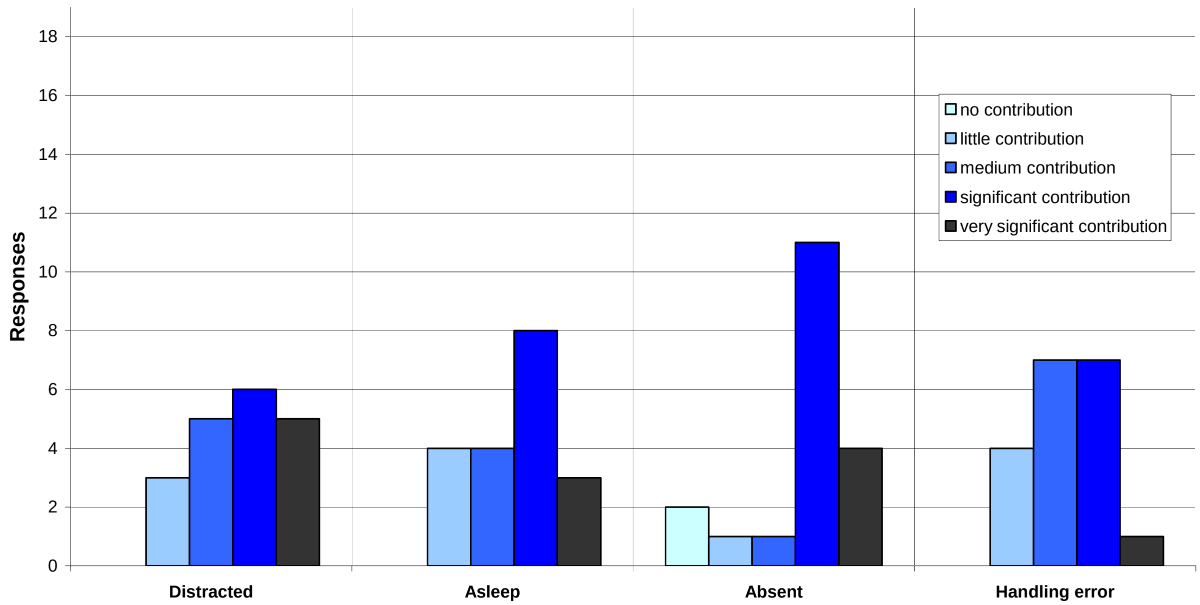
Comments during interviews

-

Over reliance on technical equipment



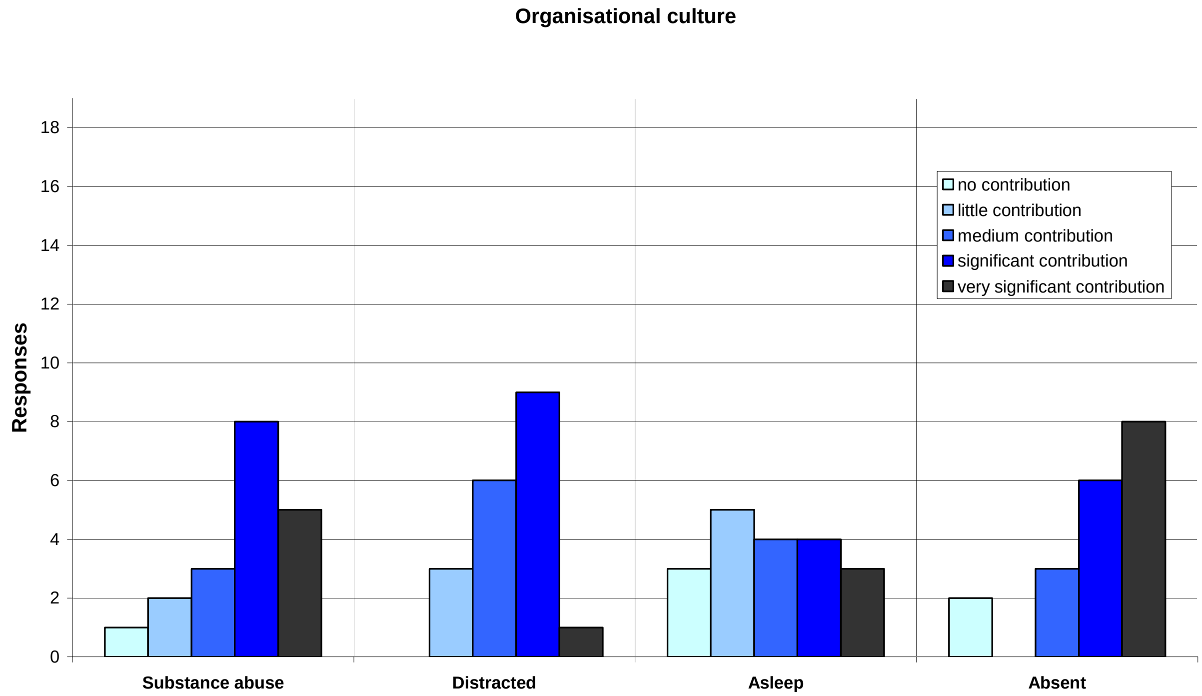
Data from literature review

There have been several accidents that probably could have been prevented if the officer on watch had looked out through the window and not only relied on instruments (Lang 2000). This could depend on how situational awareness decreases when the amount of technical automation increases (Grech et al 2008). Officers on watch tend to place more reliance on radar and ARPA (Automatic Radar Plotting Aid) to maintain a lookout. Technology has advanced and the number of crew members has decreased which have lead to changes of the bridge watchkeeping practices in recent years. (MAIB,2004)

Regulation and new technology may have led to the perception that the master's responsibility has been reduced. This can affect their ability to provide clear leadership and be self-sufficient. Perceived ownership of safety management may also have been reduced. (Maritime & Coast Guard Agency, 2006)

Comments during interviews

Several respondents believe that it is common with over reliance on technical equipment (Carl-Henric Wulff, 2008-11-10; Stefan Lindberg, 2008-11-14; Michael Manuel, 2008-11-14).

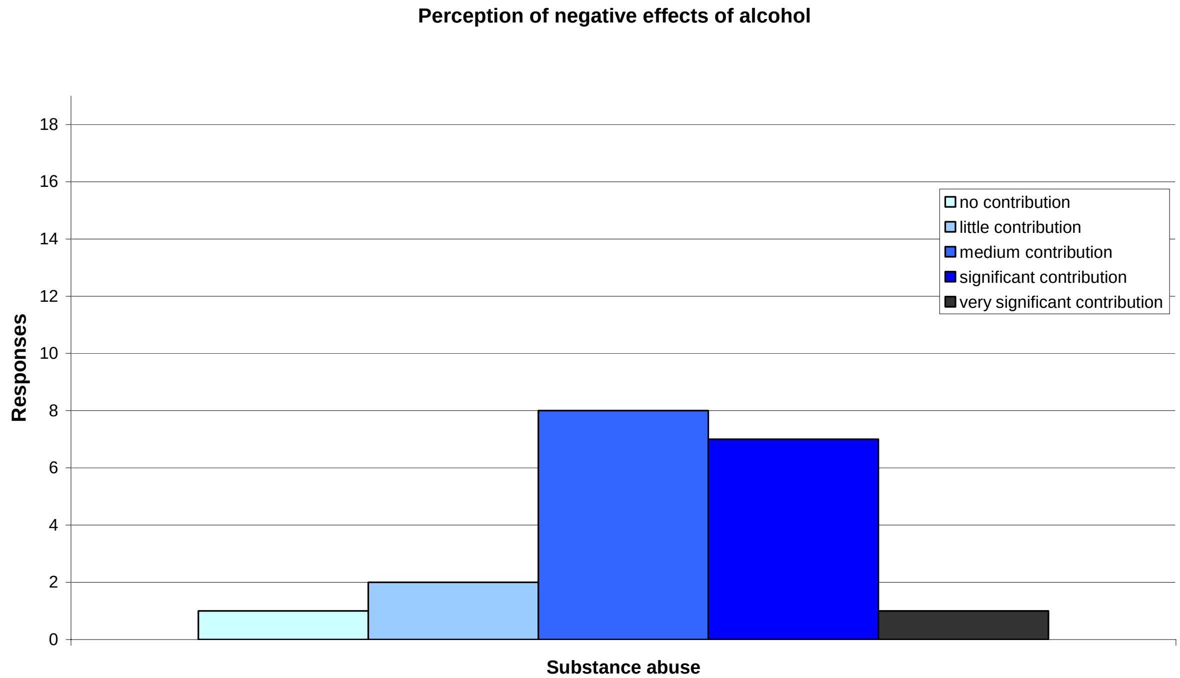


Data from literature review

Organisational culture is mentioned as one of the most important managing and organisational factors for groundings of tankers (Brown & Haugene, 1998). There exists an important relationship between safety climate and performance (Hetherington et al,2006). Individual behaviour is influenced by the organisation and one way of inducing optimum behaviour is to develop a good safety culture (Grech, 2008).

Comments during interviews

-

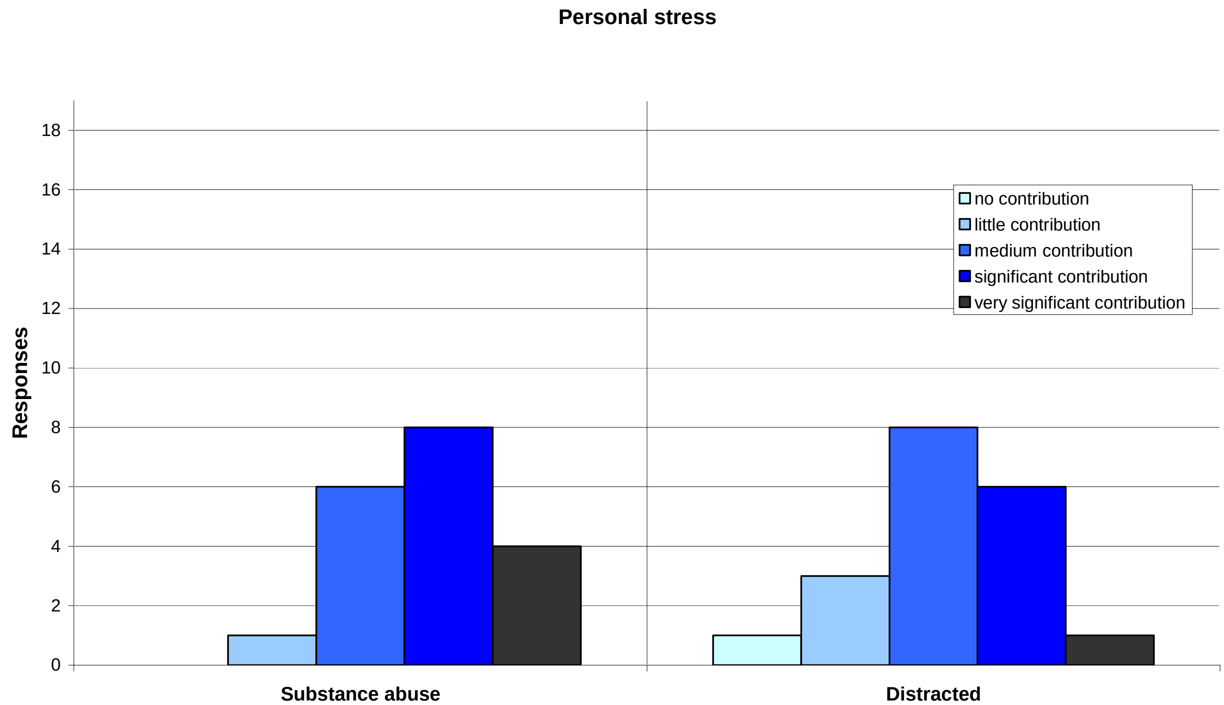


Data from literature review

Wang & Zhang (2000) are considering overconfidence as a leading cause for human error which perhaps also could be connected to the perception of negative effects of alcohol (or lack of it).

Comments during interviews

-

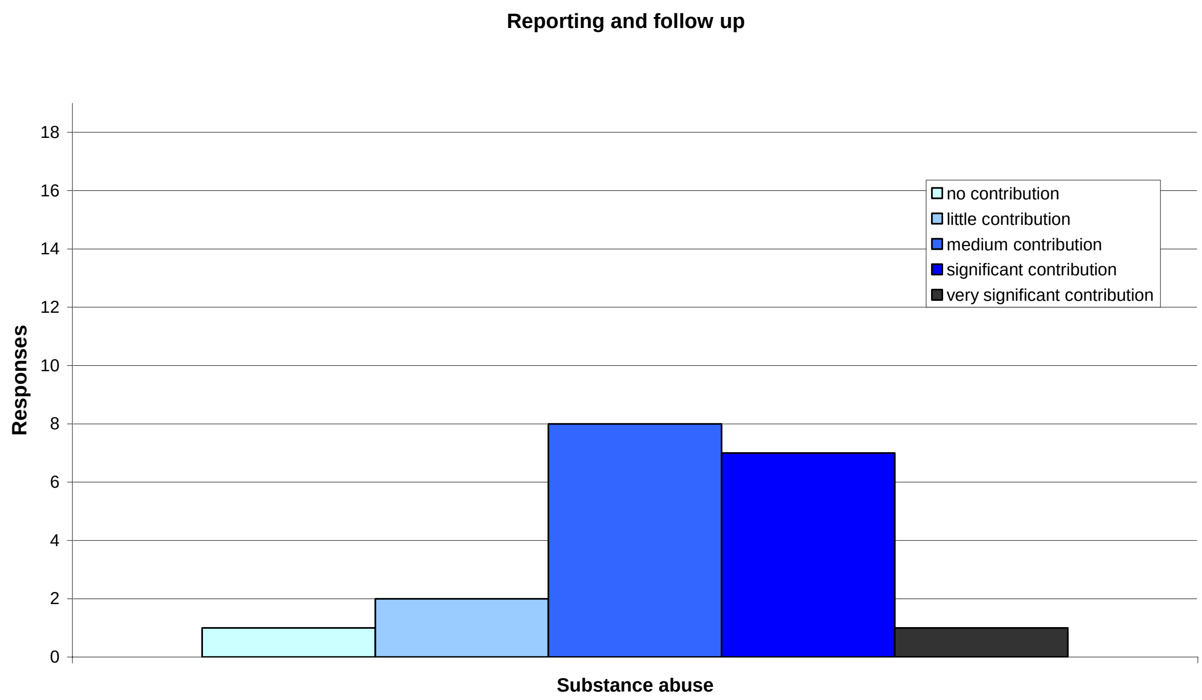


Data from literature review

Over the years, there have been an increasing number of studies investigating stress at sea. Stressors like being away from family and friends during long periods at sea can affect most crew members (Grech et al, 2008). Personal tasks such as telephoning or writing home have to be completed (MAIB, 2004). It is also stated that stress is not a stranger to the average mariner whereas stress management has no focus within the marine community (Lang, 2000).

Comments during interviews

It was indicated during an interview that work pressure and personal stress is very specific to an individual (Jens-Uwe Schrøder, 2008-11-13).

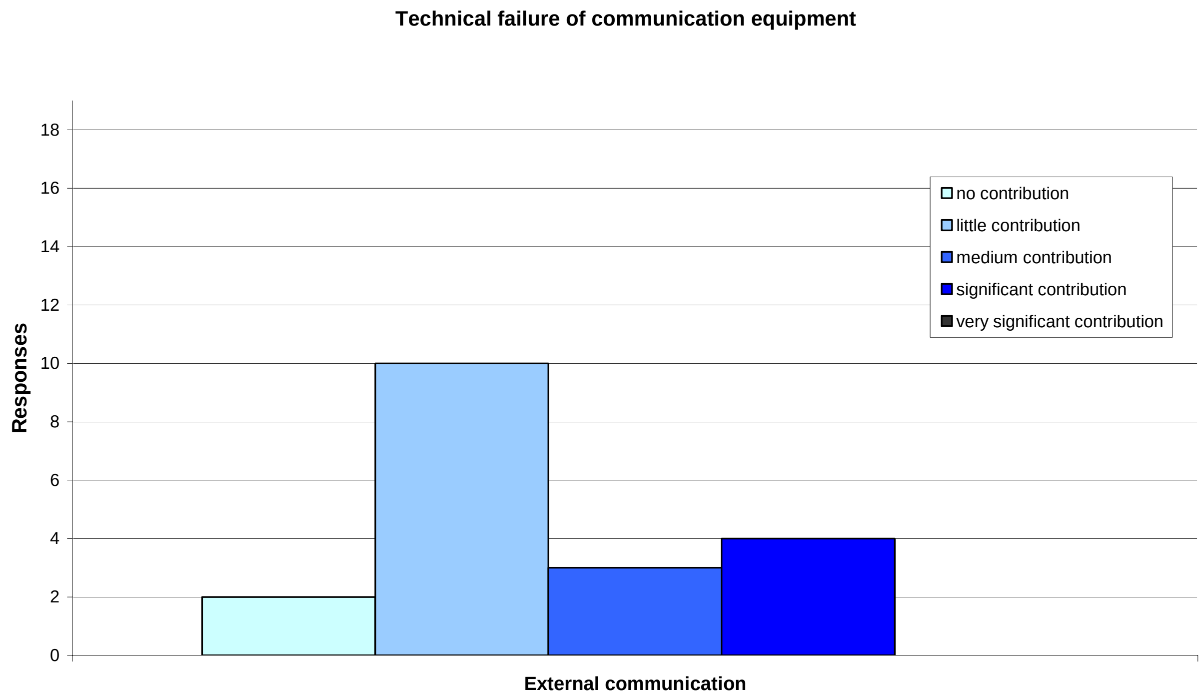


Data from literature review

There is data about the importance of reporting and follow up (e.g. Maritime & Coast Guard Agency, 2006) but not connected to any accident statistics.

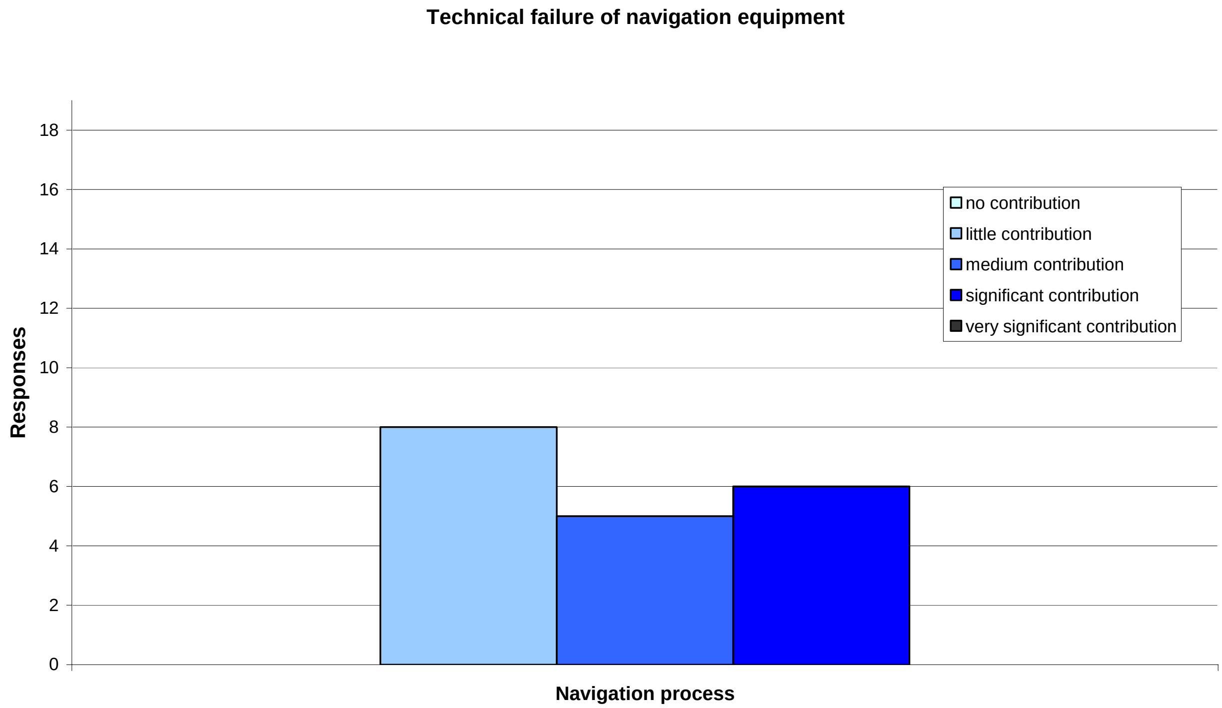
Comments during interviews

-



Data from literature review
In a report by De la Campa-Portela (2003) it is described how 18% of all communication problems are related to the technical equipment.

Comments during interviews
A conclusion is drawn that a technical failure of the communication equipment is not a likely reason to errors in communication, due to how several means of redundancy exists (Carl-Henric Wulff, 2008-11-10).

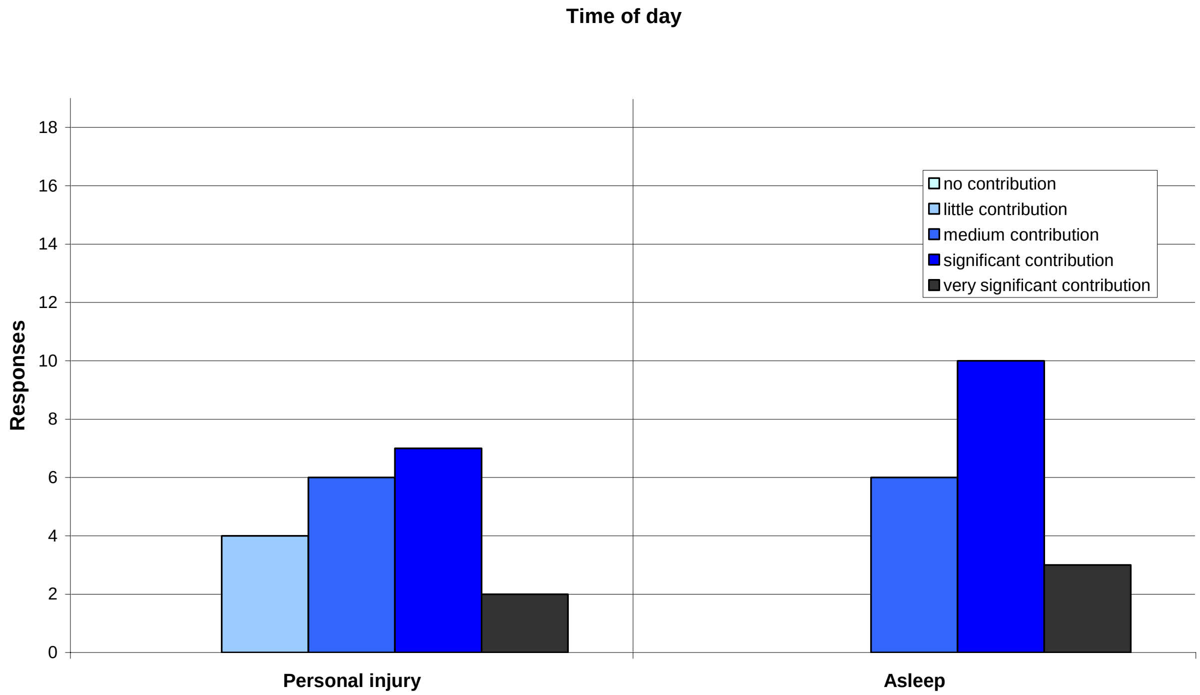


Data from literature review

Sources of literature indicate that the impact of technical failures on the navigation process is very small, less than 1% (TSB, 1998).

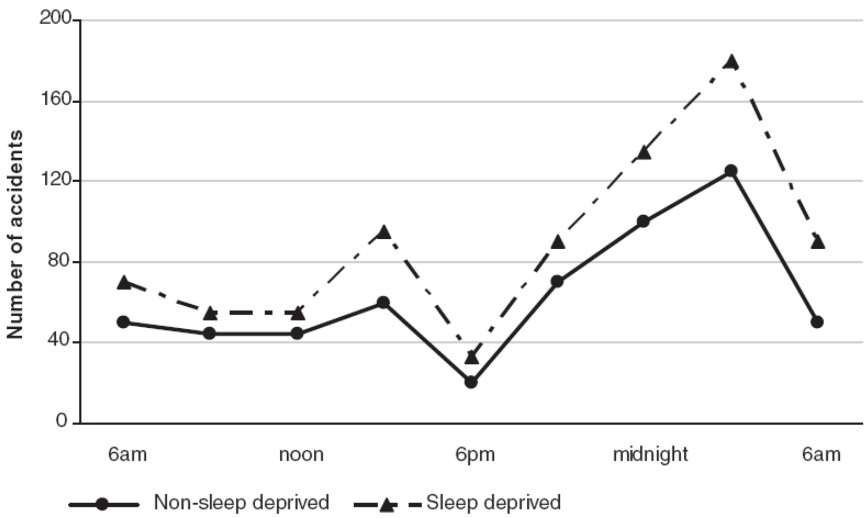
Comments during interviews

It was mentioned by one of the participants in the expert judgment that there is redundancy in the navigation equipment and a technical failure would therefore not be likely to directly cause a navigation error (Steven Sawhill, 2008-11-07).



Data from literature review

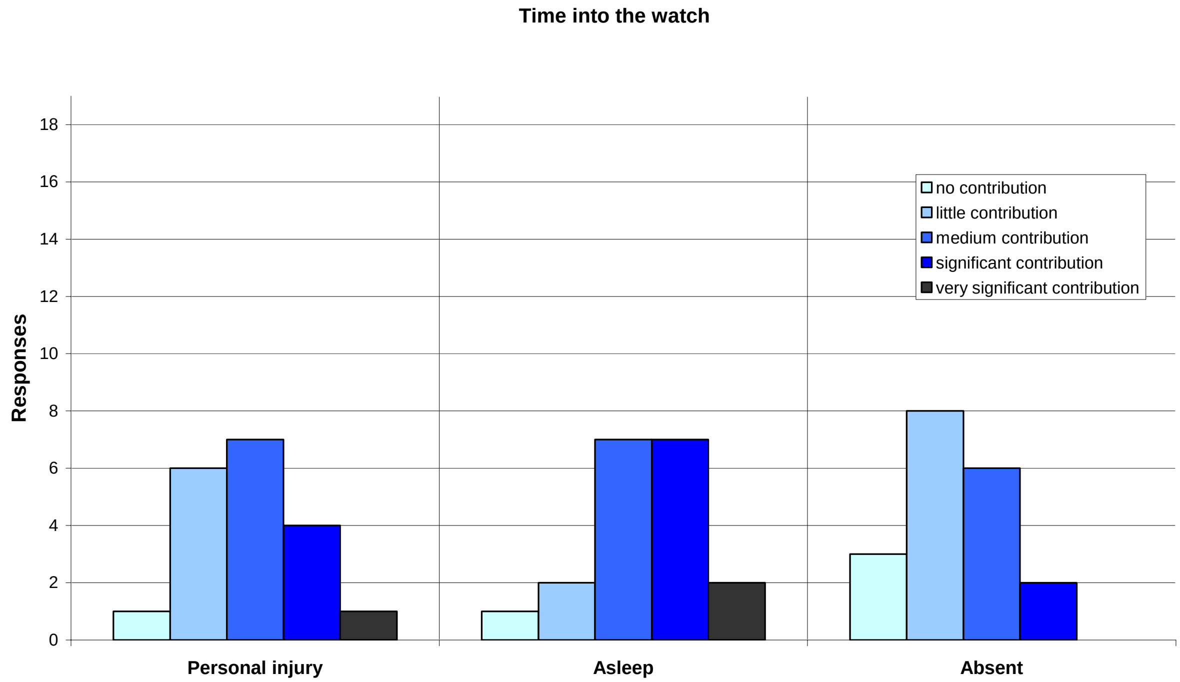
Most of the statistical material about accidents and time of day is connected to fatigue. It is for example stated that the number of incidents is increasing during early mornings and afternoons (Grech et al, 2008). Approximately 77% of the accidents when sleep was identified as the primary cause occurred between 00-08 (Philips, 2000). Research has shown that alertness and performance tend to be lowest during the early hours of the morning (MAIB 2004).



Typical example of the number of errors/accidents as a function of time of the day (Grech et al, 2008).

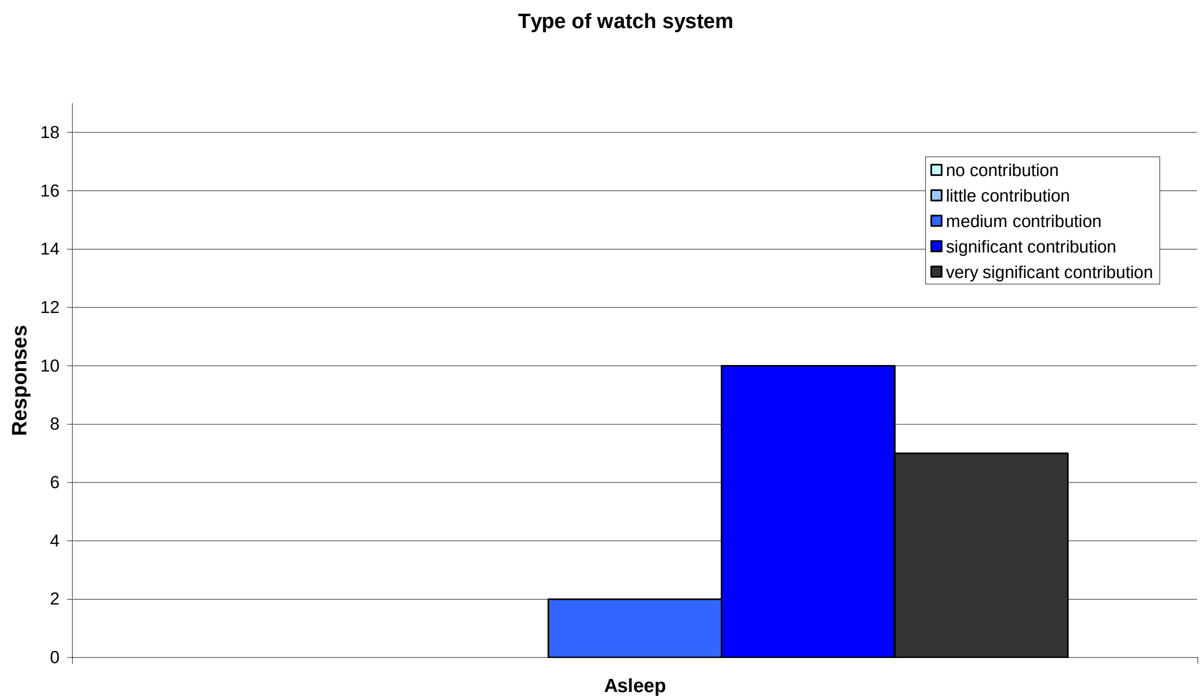
References from the literature review are regarding early morning as the time when most accident occur and time of day is therefore also an important factor to why an officer on watch falls asleep.

Comments during interviews
It is a view amongst several of the respondents that the hours between midnight and morning are the toughest (Helge Samuelsen, 2008-11-04; David Wendel, 2008-11-07; Michael Manuel, 2008-11-14; Jens-Uwe Schrøder, 2008-11-13).



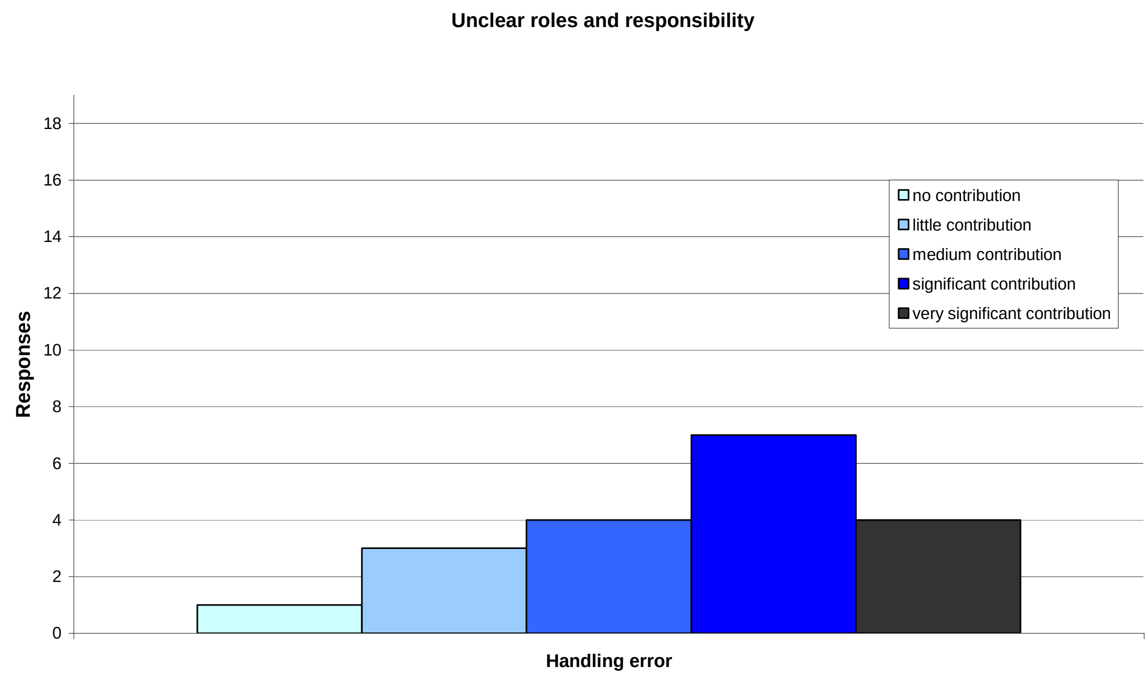
Data from literature review
Performance tests have shown that the alertness and concentration of lookouts is diminished after about 30 minutes on watch (MAIB, 2004). Sleepiness is more frequent in the end of a watch, especially with a two watch system (Lützhöft et al, 2007). There is a fairly widespread acceptance by the research community that long hours contribute to fatigue and therefore also to errors, incidents and accidents at sea (Grech et al, 2008).

Comments during interviews
Time into the watch should not be a problem if the ship has a 4/8 watch system (Carl-Henric Wulff, 2008-11-10).



Data from literature review
It is most likely that an accident takes place on the third watch in a 4/8 watch system, i.e. 04.00-08.00 (Nielsen & Jungnickel, 2003). The type of watch system implemented on a ship is most often discussed in relation to fatigue and is therefore considered to be closely connected to accidents. The type of watch system is consequently perceived as an essential factor in the risk for collisions. Officers in a two-watch system are sleepier than officers in a three-watch system, especially in early morning and afternoon. Sleep quality is low for both shift systems. (Lützhöft et al, 2007)

Comments during interviews
The type of watch system is important and 4/8 watches are considered to be better than 6/6 (Tor Egil Hopen Saue, 2008-11-03; Helge Samuelsen, 2008-11-04).



Data from literature review

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Comments during interviews

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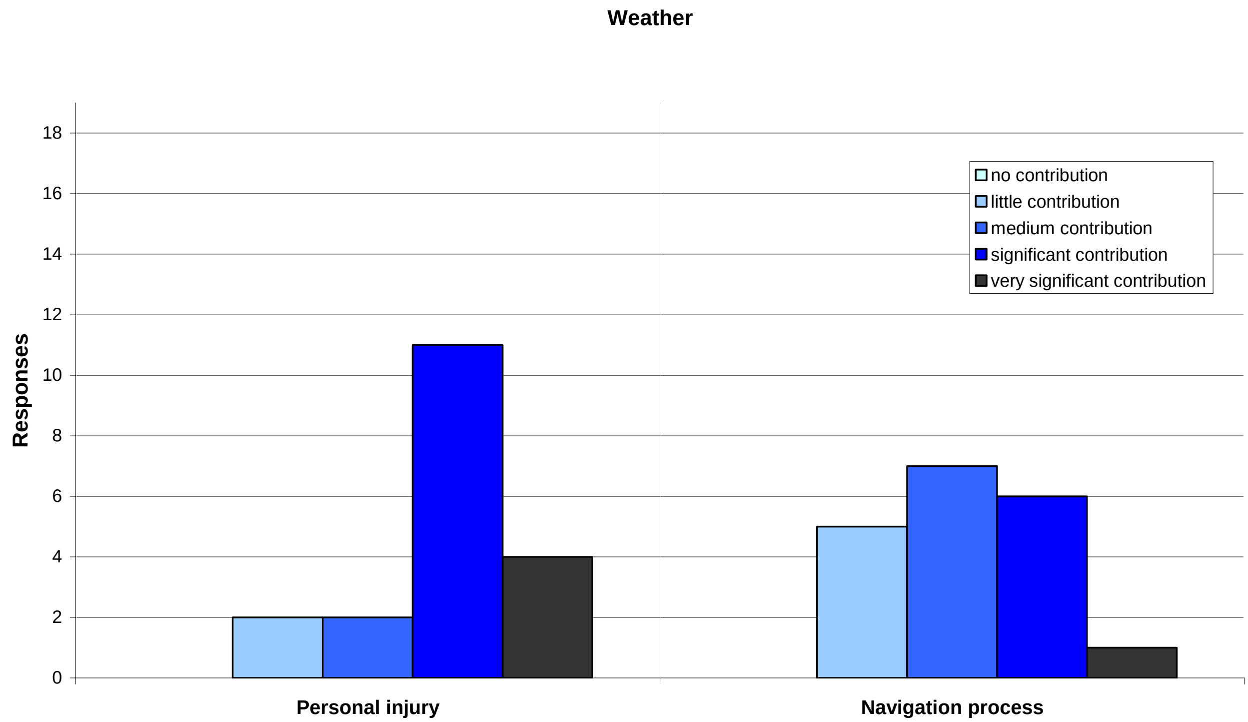

Data from literature review

Some inconsistency is found within literature related to the influence of weather in accidents. A majority of all incidents actually happen in good visibility according to accident reports (e.g. MAIB, 2004). The weather is also found to be an underlying factor and e.g. cause 11 % of all accidents in USCG data (Baker & McCafferty, 2005).

Comments during interviews

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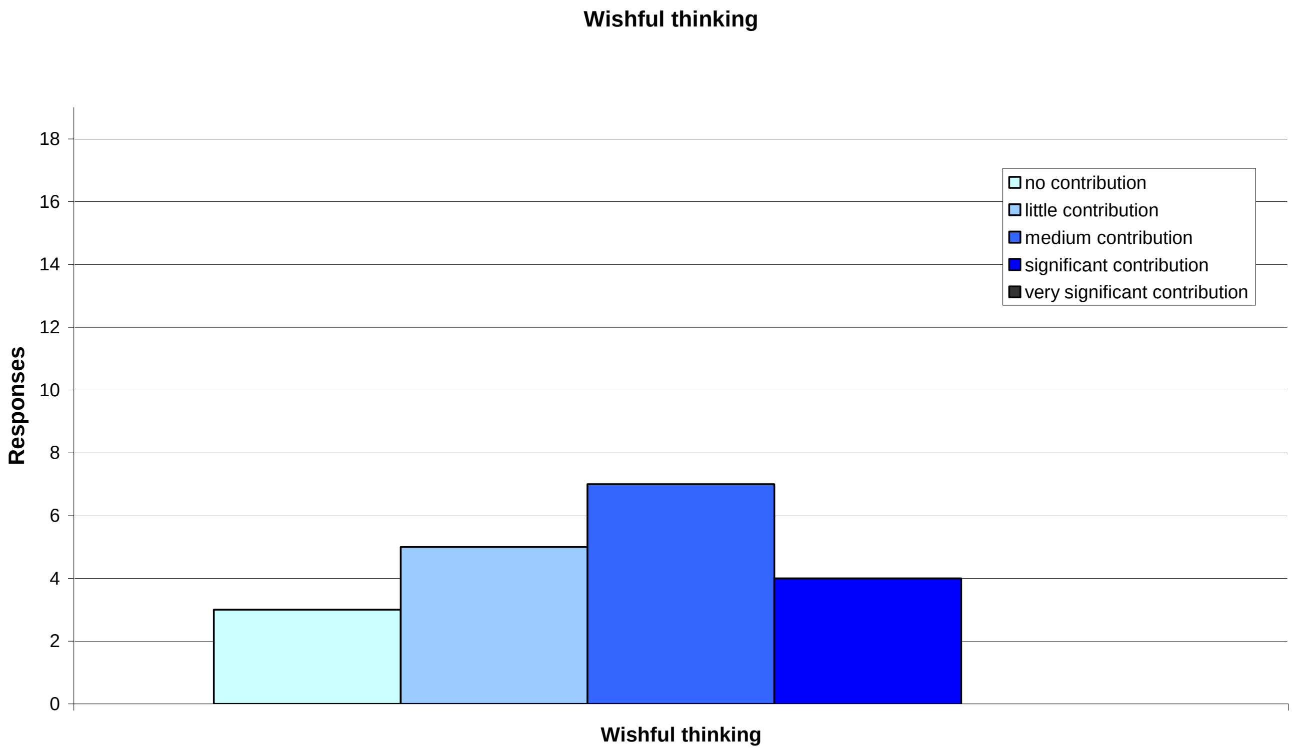

Data from literature review

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Comments during interviews

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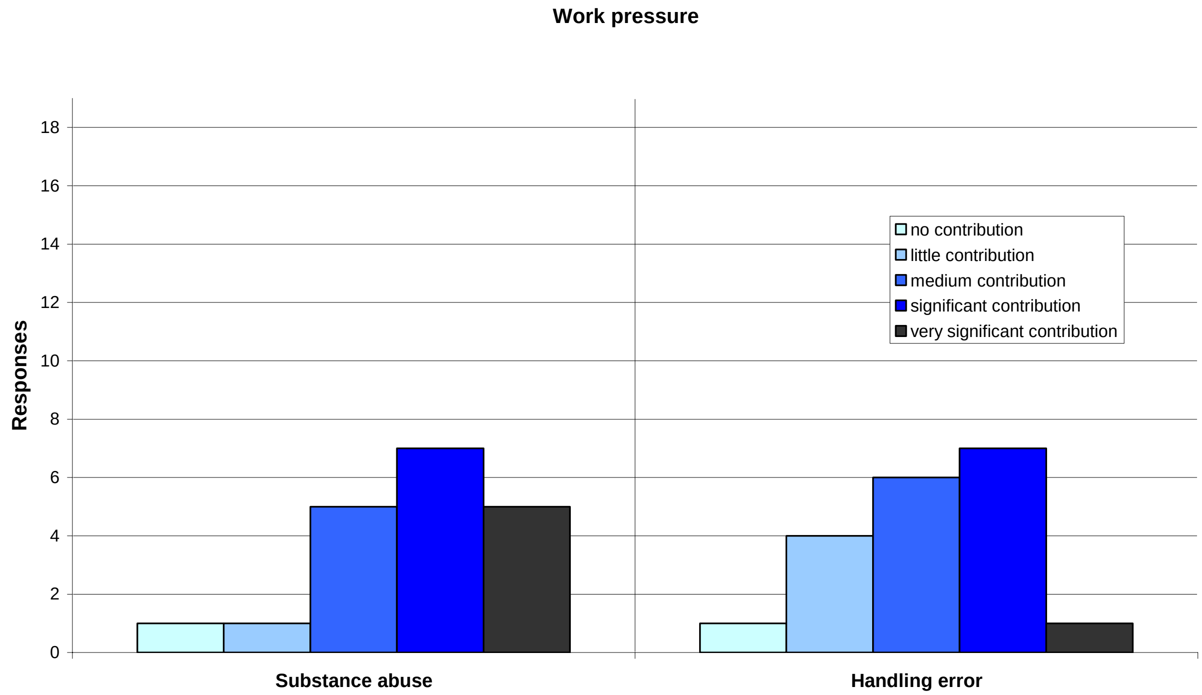
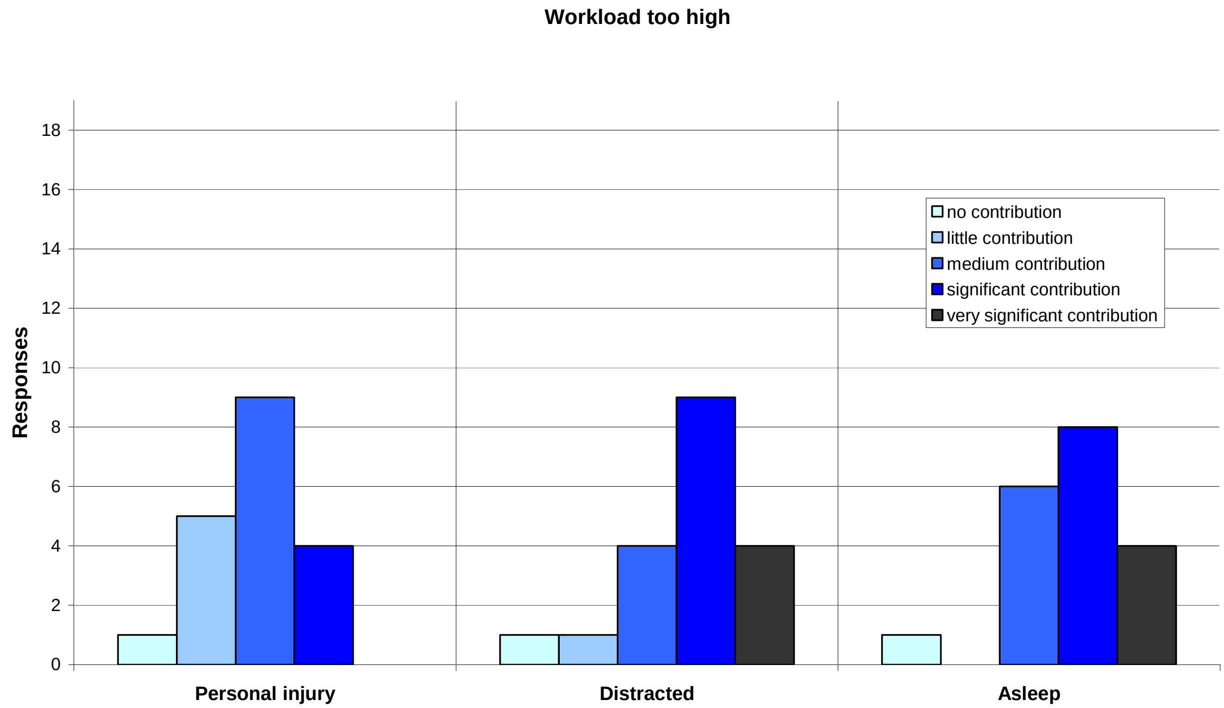


Data from literature review

Time pressure is mentioned as a contributing reason in accident reports from the Swedish Maritime Administration (2008). Other than this, the impairment of a high economic pressure or time pressure within a maritime organisation is not often referred to. MAIB (2004) however mentions work pressure as a contributing factor for fatigue.

Comments during interviews

It may sometimes be a fact that economical values are prioritised over safety (David Wendel, 2008-11-07).



Data from literature review

A high workload is one of four management and organisational factors that Brown & Haugene (1998) estimated as having the greatest impact on groundings. According to another research project, workload is likely to be the origin of 32% of all scenarios when an officer on watch is incapacitated (Kristiansen & Soma, 1999). Paper work associated with regulations and requirements for ship/shore reporting can increase the workload, hence having a negative effect on safety (Maritime & Coast Guard Agency, 2006).

Workload is also discussed as a factor for fatigue in the literature and assumed to be a contributing factor for a person falling asleep.

Comments during interviews

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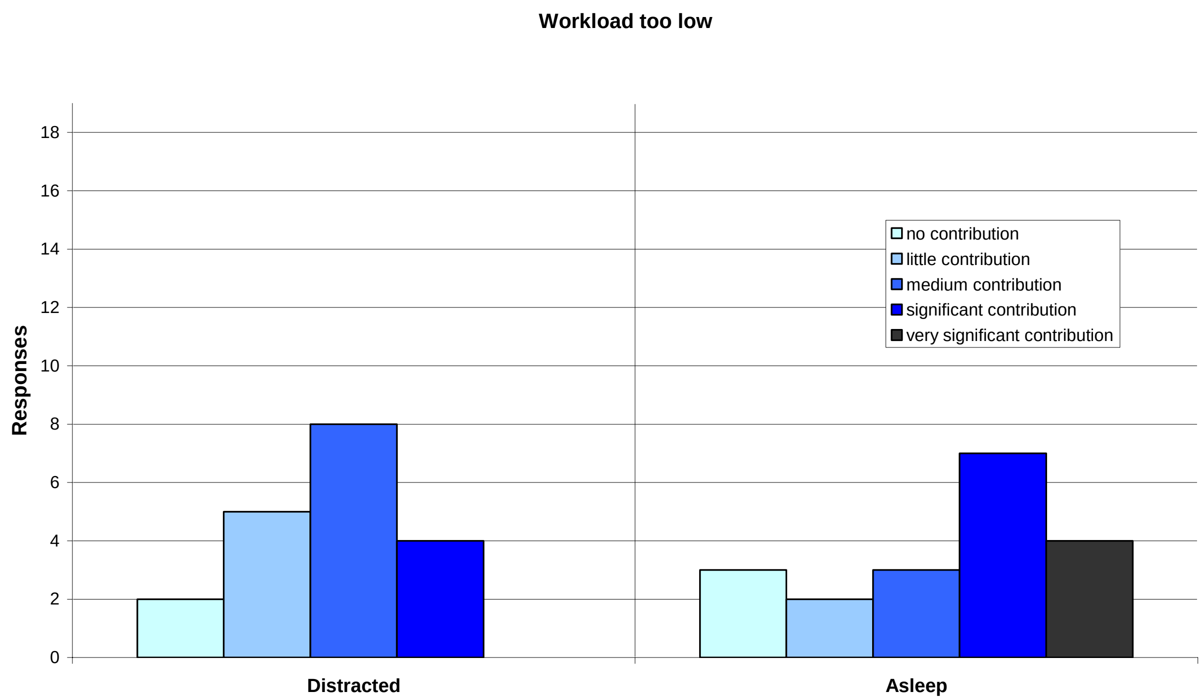

Data from literature review

Having so few tasks that a person gets under stimulated and bored is likely to depend on the geographical location, the activity of a ship and the duration of a voyage. A low workload is often discussed in relation to automation and the boredom that this may create, but there are no statistics of how often this would happen or to what extent a low workload is a contributing factor to accidents (Lützhöft et al, 2007).

Comments during interviews

Situations related to a low workload have been mentioned during the interviews, for example how crew members watch videos during their watch. It was pointed out that errors usually happen when the workload is low, after a long period with a high workload (Petter Øverås, 2008-11-04; Tor Egil Hopen Saue, 2008-11-03).