UiT
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Faculty of Science and Technology
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Analysis of potential critical equipment and technical systems on a modern PSV

Recommending a method for Troms Offshore Management AS

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Master thesis in Technology and Safety in the High North
June 2016

1 Acknowledgement

I want to express my sincere gratitude to my supervisor Bjørn Batalden, for the support and help during the process of completing this thesis. His knowledge of both the subject and the shipping company has been most valuable.

My dear coworkers at Troms Offshore Management AS must also be mentioned. Thank you for keeping me motivated at all times during the last two years! Thanks to Jan-Arild Karlsen and Morten Haugan, our Technical superintendents, for showing genuine interest in my work and for answering all my numerous questions on the equipment and practice on board the vessels.

I would also like to express my gratitude to Hilde Kjerstad who introduced me to the problem, and for all brainstorming and laughter she has provided along the way.

Last, but not least, a big thanks to our crew that took their time to read through and reply their opinions on my work.

Signy Anita Løvmo

Tromsø, May 2016

2 Abstract

This thesis is a part of a master's degree in Technology and Safety in the High North at the University of Tromsø- The Arctic University of Norway. The thesis has been written during the spring semester of 2016.

Safety is a large part of maritime operations and all tools to improve safety and reliability is considered. Even in these days when economy in the oil related industry is worse than ever. The International Maritime Organization (IMO) ensures that all suppliers and contractors are obliged to follow rules and regulations in order to ensure a safe workplace for all members the industry and protection of the environment all over the globe. One of those regulations is the International Code for Safe Operations of Ships and Pollution Prevention (International Safety Management (ISM) Code) paragraph 10.3:

"The company should identify equipment and technical systems the sudden operational failure of which may result in hazardous situations. The SMS should provide for specific measures aimed at promoting the reliability of such equipment or systems. These measures should include the regular testing of stand-by arrangements and equipment or technical systems that are not in continuous use."

The subject of the thesis is "Analysis of potential critical equipment and technical systems on a modern PSV- Recommending a method for Troms Offshore Management AS". The thesis will look at several methods that may be used to comply with the ISM Code 10.3. These methods is tested on an equipment or technical system that is used on a vessel in the Troms Offshore fleet, whereas those tests was presented to two expert panels in order to obtain information on how these methods are interpreted and found usable in practice.

The method that is most suited in regards to being able to perform for all equipment and technical systems, being understandable for the intended readers, being constructed in a way that everyone can achieve the same result and being able to express enough information that everyone can access the reason for why the conclusion is what it is will be recommended for further use in Troms Offshore.

Based on the feedback from the expert panels and the authors analysis was a method designed by the author, The Ajabu method, found most suitable. Some improvements was done before the method became recommended for use.

Key words: ISM Code, maritime safety, hazardous situation, PSV, sudden failure, SMS, method, analysis, offshore.

3 Definitions

Beam	Widest width of a vessel.
Bow	Front area of the vessel.
Bridge	Navigation control room.
Cadet	Future officer under training to get the first certificate.
Call sign	Unique letter/number combination to identify the specific vessel. Shows nationality.
Chief Engineer	Head of engine department.
Chief Officer	Second in command of deck department.
Class	A standard that specifies equipment, design, etc.
Coxswain	Driver of the lifeboat/FRC.
Crew	Person that is performing a job on board a vessel when the vessel is not moored.
Dacon scoop	Net that can be used to collect objects from the sea.
Davit	Crane device that launches lifeboat/FRC.
Deck	Floor on the vessel.
Displacement	The weight of the water the vessel displace. Is equal to the weight of the vessel.
Draught	The vertical distance from the waterline to the keel.
Freeboard	The vertical distance from the upper watertight deck to the waterline.
Harbor	Natural or man-made place where vessels can be laid up or take shelter.
Heave	Up- and down motion
Hull	The "shell" of the vessel.
Immersion suit	Suit designed to protect person from water and cold.
Keel	The bottom of the construction. The centerline seen from above.
Knot	Measure of speed. One knot equals one nautical mile per hour (1,852km/h).
Ladder	Stairs on board a vessel.
Master	Highest in command of the vessel.
Nautical mile	Measure of distance. One nautical mile equals 1852m.
Port	Direction. To the vessels left hand side in traveling direction.
Starboard	Direction. To the vessels right hand side in traveling direction.
Stern	The aftermost part of the vessel.
Superstructure	A building above the deck. For cabins, storage, bridge etc.
Thruster	Propeller which works perpendicular to the centerline.
Trainee	Future rating in training to get first proficiency certificate.
Vessel	Craft that is, or may be, used for transportation on water.
Waterline	Where the sea surface reaches in upwards vertical direction on the hull.

4 Abbreviations

ECDIS Electronic Chart Display and Information System

FRC Fast Rescue Craft

LOA Length Over All

LPP Length Per Perpendicular

MOB Man Over Board

OS Ordinary Seaman

OSV Offshore Supply Vessel

PSV Platform Supply Vessel

SAR Search And Rescue

SFI Skipsteknisk Forskningsinstitutt

SMS Safety Management System

IMO International Maritime Organization

DWT Dead Weight Tonnes

ECR Engine Control Room

DNV Det Norske Veritas

MV Motor Vessel

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7 Introduction

7.1 Background

I knew that the master's thesis was under way and have kept it in mind all the way since I started at Troms Offshore in 2014. Writing a practical thesis where I can combine my nautical competence, the curriculum from the master's program and real life issues is to me the best way to complete this task. The maritime aspect is the one I am familiar with and like to study. I have tried to relate all the curriculum to this earlier in the program in order to understand it in a way that can relate to practical and real problems, not only invented issues that are designed in a way that make it relatively easy to find the correct solution.

The QHSE manager at Troms Offshore Management was in the spring of 2015 asked if she had any ideas or knew of something that could be a proposal for a master's thesis. She then mentioned that the way they had set up an analysis of critical components could be improved. It had been started in another way as well, but this had focused very on the component level and not entire systems and possible connected systems. The Managing Director has also a couple of suggestions that was problems they have experienced earlier and wanted to have analyzed or improved.

I thought about all these suggestions for a while and tried to figure out which one of those that would fit my study the most and if it had the potential of being a master's thesis at all. The choice fell finally on the critical component analysis. I believed that this choice would be a good opportunity for me to really learn the different analysis methods that had been lectured over the last year and how to apply them in real life.

The maritime field, among others, is not easy to analyze by using common methods. A system that on shore can be replaced or fixed in no time will have the potential to be a greater threat on a vessel or offshore installation that do not have all possible spare parts or professionals available. They often have to deal with what they have on board at all times, which means that the tolerance of faults is lower than onshore. I hope that this will come forward in the thesis and I am curious to see how visible this is when trying to apply common methods that work on general systems.

7.2 The International Management Code for Safe Operations of Ships and Pollution Prevention

"During the 1980s and 1990s, the shipping industry experienced several very serious accidents. From the investigations into these accidents, it was evident that major errors related to poor management. As a response to these developments the International Maritime Organization (IMO) adopted Resolution A.741(18), which constitutes the International Safety Management (ISM) Code in 1993 (IMO 1993). The purpose of the ISM Code "is to provide an international standard for the safe management and operation of ships and for pollution prevention" (IMO 2010, 10). The ISM Code introduces an enforced self-regulatory mechanism whereby shipping companies themselves regulate their activities to achieve safety. The term "enforced selfregulation" is applied when typical management-based commands are used, involving a type of negotiation between the regulator and the individual firms (Baldwin, Cave, and Lodge 2010). The aim is to ensure that proper regulations are established for the specific firm." (Batalden, 2015)

The reasons for creating an overview of critical components can be various depending on the field of operation. Nevertheless, the ISM Code is stating this need in paragraph 10.3:

"The company should identify equipment and technical systems the sudden operational failure of which may result in hazardous situations. The SMS should provide for specific measures aimed at promoting the reliability of such equipment or systems. These measures should include the regular testing of stand-by arrangements and equipment or technical systems that are not in continuous use."

The Code establishes safety-management objectives and requires a safety management system (SMS) to be established by "the Company", which is defined as the ship-owner or any person, such as the manager or bareboat charterer, who has assumed responsibility for operating the ship. (IMO, 2016)

Codes and guidelines, which both exists an excessive number of, is voluntarily in the first place. In this case is the Code implemented in a mandatory convention named SOLAS (Safety Of Life At Sea). SOLAS is a result of the RMS Titanic disaster in 1912 and was adopted the first time in 1914. Several of the major regulations is a product of experiences and observations of larger accidents at sea. According to SOLAS is the Code applicable for all passenger vessels carrying more than 12 passengers in foreign trade, cargo vessels with gross tonnage above 500 in foreign trade and movable installations.

(Regjeringen, 2008) claims that Norway as early as 1991 adopted a regulation stating that all passenger vessels in domestic waters (no regards to trade area or class) that carries more than 100 passengers shall have a safety management system. This following the Scandinavian Star accident.

7.3 Discussing paragraph 10.3

Already in the first sentence of the paragraph are words that require a definition and understanding. The Code and the guidelines (International Maritime Organization, 2013) does not elaborate any of them so the following definitions may be interpreted different from company to company, within reasonable limits of course.

The word sudden can mean several periods of time in different contexts, but here is it most natural to think of it as immediate. A component of unprotected steel mounted on deck will corrode over time and possibly perform its tasks in a less satisfying way during this time, but it will not be until this fall or breaks the sudden failure is a fact. The intention should be that the corrosion rate is monitored so that the component can be replaced before it is weak enough to provide a sudden failure, or perhaps choose another material or placement for this component if such is available and a possible solution.

Hazardous situation can also mean several different things. If the situation can cause loss of life will everyone define it as hazardous, but if it result in other damages can the line be hard to place. In 11.3 is a hazardous situation defined as an event that directly or indirectly can lead to physical or psychological trauma to a person that is directly or indirectly present, or be a threat to the environment.

The paragraph states also that the sudden failure is not required to result in a hazardous situation, only that this may happen. Not everyone has the same attitude to safety so the chances are that if the paragraph stated “will result in a hazardous situation” some would analyze that the probability of a given scenario resulting in a hazardous situation to be so small that the equipment or technical system therefore is not critical. That would be an unnecessary dangerous decision to make. By using the word may does IMO open up for brainstorming in the safer direction. There are of course reasonable limits here as well, but overdramatizing might actually reveal hidden hazards that can be crucial to the safety and reliability.

Operation in the arctic will entail challenges that is not found elsewhere. It is known that several institutions in Norway and elsewhere has completed research on icing and temperature influence on materials, but with predicted increased maritime activity in the high north is it probably necessary with further research and presentation of results. Steel and other common materials is well tested and it is known how this material will react to temperature drop, but within a modern PSV is it several equipment and technical systems that consists of other types of material that may not have been tested well enough. The technological development will probably also provide us new materials and compositions with new properties and other reactions to temperature and wear. These test results should be carefully reviewed by the Company, or whom they delegate the task to, to ensure the reliability of current and planned equipment and technical systems on board vessels.

As per now has is not been done anything in the design of the TOAS vessels that will make it easy to get them ready for arctic operation, except the ice-class of Arcturus and the FRC garage on Arcturus and Troms Pollux.

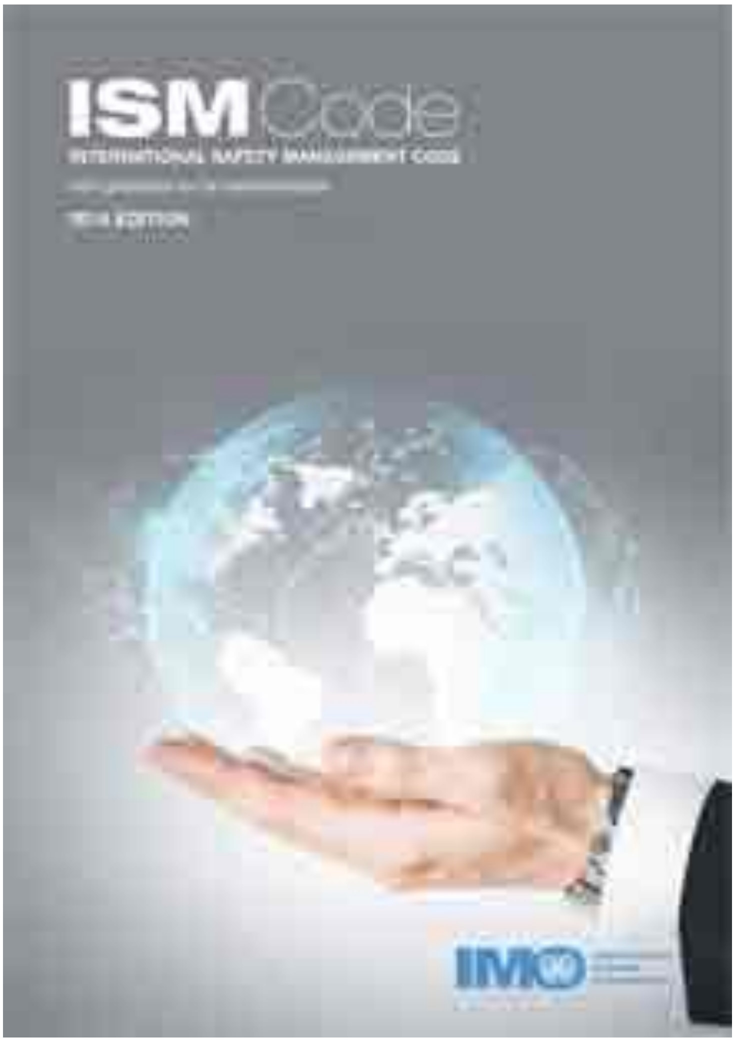

Figure 1- ISM Code (IMO, n.d.)

7.4 The group conducting the analysis

No matter how perfect the method used are, there is always a possibility to capsize the whole thing in very few steps. Even if the method has all possibilities to identify barriers, prevailing circumstances, connected equipment and technical systems, visualize the criticality and be functioning on all possible components will it possibly fail dramatically if the team conducting the analysis is unqualified.

If you are to describe a scenario of which you have no familiarity with will it all be fantasy or the illusion you might have received from experiences in the past. There is absolutely no guarantee that this is the correct outcome, in both a positive and negative way, and the risk of a great hazard sneaking under the radar is intolerable high.

The completed analysis will be available for several people to read, but there will be a limited group of people that will process the different equipment or technical system through the method to evaluate if those shall be categorized as critical or not. This group will in the TOAS case most likely be the QHSE department and/or Technical superintendents.

A list of elements of competence that often is required is found in Rausand (2011, p.134).

- Knowledge/understanding of the study object
- Probability theory and statistics
- Chemical, mechanical, electrical, structural, or nuclear competence
- Health competence, including toxicology
- Social science, including economy, psychology and sociology
- Human factors and human reliability
- Organization and management and the impact of safety

All these is reasonable to see in connection with a maritime analysis of criticality. Finding one person with all this competence will be hard, but also not a preferred situation. Brainstorming among two or more persons with a different field of expertise and different impressions can make the process more secure as one person may focus on one part and the other on the next so that they in the end have the possibility to get the whole system covered.

Being at sea anywhere in the world will include another type of environmental stress that the same equipment or technical system will experience onshore. Those performing the analysis onshore needs to remember this as the mariners will not naturally consider how things work onshore, and suppliers that supply equipment or technical systems that can be used both places probably will present test results from an onshore installation in general.

7.5 Research problem

Stating the research problem of this thesis:

"Recommending a method for analyzing equipment and technical systems in order to conclude if the technical failure of which may result in hazardous situations."

In this thesis shall a method be recommended in order to have a common setup that can be used for every equipment and technical system on the vessels managed by Troms Offshore Management AS. Five different methods will be looked upon; three commonly used methods, one found online and one that will be specially designed by the author for this purpose. The first three has been demonstrated and explained during the master's course, one has to be interpreted as it is found online, while the last one will be an attempt to combine the authors understanding of analysis theory and the maritime practice. A deeper explanation presented in 11.6.6.

A chosen equipment or technical system will be processed by each method to test their capabilities. This will be presented to two expert panel; onshore staff and offshore crew. The author will recommend a method based on this study, but the feedback from the expert panels will be made visible in the evaluations of each method and might lead to measure of improvement in the chosen method.

From the onshore staff is QHSE department, Operations department and management chosen. Those people are those who will come in direct contact with this analysis in the future. They have varied ages and background, some are former mariners and some academically trained. They are all Norwegians and have good knowledge about the TOAS vessels.

The offshore crew group will have a wide range in age, nationality and rank. Both officers and ratings is offered the opportunity to contribute. The common denominator among them all is the education and training that fulfills the STCW regulation, and the fact that they are all employed on a PSV.

7.6 Limitations

The available time to complete this thesis will set several limitations, mostly on the number of methods and equipment/technical systems tested, but also on the quantity of expert participants. If the number of one or more of those increases will the amount of information to process into informative text, also increase. Therefore have the author sat a limit that is believed possible to process, as well as high enough to give a representative outcome.

A modern PSV has more than 500 different equipment or technical systems on board, some critical and some not. At least two of those is preferred tested in order to achieve variety, but due to time limit might this end up only partially completed so discussion will therefore be used instead. It will also be hard to decide and prove that those two equipment or technical systems is different enough and together will have the power to determine strength or weaknesses in the method.

There will not be enough time to get to know the equipment or technical system on a component level either. The focus will be on the methods and the necessary knowledge to perform them in a way that that will demonstrate their abilities. There will be a discussion on each method instead where it is discussed if it will work on different systems that might exist on a PSV without them being the exact version mounted on the chosen vessel at TOAS.

The human factor involved in operation of equipment and technical systems will not be measured and analyzed in the methods. Nevertheless is it an important theme and crucial to keep in mind when performing such analysis so a chapter will be dedicated to this. Chapter 11.2 will both explain why this is excluded, what may be partially included and which aspects that should be remembered even if they are not included in the analyses.

7.7 Structure

The background for the thesis and the planned work has now been presented. We will now find general information on the author, Troms Offshore and one of their vessels so that a relation to what outer factors that had to be considered during the writing of the thesis. Before the methods are presented will theory on barriers, threats, risk acceptance and methodology be listed in order to have such in mind when methods are considered.

After the methods are presented will those be analyzed first by the author and then by the expert panels. From this will a conclusion on which of the methods that are most suitable be drawn. Recommended future work and validation is then mentioned.

Attached is the information which was sent to the expert panels attached. This is almost the same as listed in the presentation of the methods, but some information is left out.

8 Presentation of the Author

This master’s thesis is handed in by Signy Anita Løvmo and as the final work at the master program in “Technology and safety in the high north” at UiT- The Arctic University of Norway. I completed my bachelor of engineering in nautical science at the same university in 2014 and started this 2 year program directly afterwards. During these two last years have I also been working at a local shipping company where I am so lucky to combine job and passion. My employer has also been so kind to agree that I could write my thesis in collaboration with them.

After completing the bachelor study my classmates start their journey to end up as master mariners, but I applied for jobs onshore only as I find the bigger picture of shipping so rewarding and exiting. To be able to combine the practical aspect of managing a vessels on a daily basis and to dive into the details and necessity of the equipment has been both educational and fun. My daily work is with the crew on board the vessels and not the vessel itself, which the engineer in me finds somewhat difficult. Therefore was this possibility to look into technical details and browse among the specs of a vessel not hard to accept.

Due to me having both the nautical background and the theory presented in the master program on various assessments do I believe have enough competence to carry out this thesis combined with supervision and good colleagues.

9 Collaborating company

Troms Offshore AS (TOAS) is a ship owner company and vessel/crew management company located in Tromsø, Norway. TOAS owns eight platform supply vessels, has full management on two platform supply vessels, full management on one research vessel and crew management on a drill ship. The vessels are split into two fleets with their own designated fleet manager that is responsible for all operational details for the vessels he manage.

TOAS was in 2013 bought by Tidewater Marine Inc. (TDW) from HitecVision. TDW is a North American shipping company and is with their almost 300 PSVs the world's largest offshore supply vessel owner. They launched the Ebb Tide in 1956 as the world's first offshore support vessel. This picture of Ebb Tide shows that a lot has changed over the past 60 years, but there is still something familiar with the design that we can recognize in modern vessels.

Figure 2- MV Ebb Tide (Tidewater, n.d.)

TOAS is the largest contractor in this field in Northern Norway and the PSVs are located in Aberdeen, Stavanger and Bergen as well as the Troms Pollux operating in the Barents Sea. RV Lance is owned by the Norwegian Polar Institute and participates in research project in both the Arctic and the Antarctic. A couple of the PSVs has earlier been engaged in Canadian waters and as a contrast has two PSVs been at Las Palmas. This illustrates that a lot of the crew has the competence needed to obtain safe operation both in arctic and tropical waters at both sunny and harsh days.

The TOAS quality policy, found at tromsoffshore.no, states:

"In Troms Offshore we strive to offer our clients quality services, in other words services that meet or exceed our client's needs or expectations. Our values; proficiency, reliability and enthusiasm form the basis upon which we build a culture of perfection, envisioning that Troms Offshore will become the very definition of excellence."

10 Troms Arcturus

In order to have real equipment or technical systems to test the methods on has Troms Arcturus with associated list of components been chosen as the lucky vessel. The Troms Arcturus (Arcturus) was delivered from VARD Aukra in 2014 and belongs to Troms Offshore Fleet 2. She carries the Norwegian flag and has a crew of approximately 15 Nordic men and women on each of her two shifts. She is 94,65 meters long, 21 meters wide and makes 16 knots at full speed.

Arcturus is a Platform Supply Vessel. She is therefore designed to carry cargo between the offshore installation and the shore base. She has a deck capacity of 1150m^2 that can carry 3400t. The deck area is reserved for solid packed cargo, but she has additional room for fluids in tanks that has a total volume of 8282,7 m^3. Normal cargo might be drill pipes, tools, chemical additives, food containers, mud and other items that a helicopter cannot carry due to size or hazard. Further details can be found at Troms Offshore's website.

Figure 3- MV Troms Arcturus (Troms Offshore, 2014)

Arcturus is a good vessel to test the method on as she is the vessel in the TOAS fleet with the highest class notations and most equipment. In other words will she provide the greatest number of different elements to choose from as well as more elements that may result in a hazardous situation if a sudden operational failure should occur. She is classed as a Standby/rescue vessel and it will be possible to evaluate systems that, if failed, not will be critical to the vessel herself, but may be a greater threat to the platform or rig she is assisting.

Offshore installations have these vessels and helicopters as their only neighbors. Weather conditions and unforeseen events may keep the helicopter on ground, so in order to obtain redundancy in emergencies takes the vessels a safety feature as well. In general are they all equipped and obliged to assist the installation and surrounding vessels if any situations occur as an addition to their transportation purpose, but some does also have an extra function where they will be taken out of the normal back-and-forth route to stand by the installation as a guardian.

Arcturus is one of these standby/rescue vessels and shall therefor meet guidelines from the Norwegian Oil and Gas Association (NOG) on top of the general IMO regulations. Not only shall the vessel be equipped in order to minimize oil spill and rescue humans, her crew shall be additional trained to perform such operations as well. NOG provides only guidelines, but most oil companies strive to be in compliance with these guidelines and therefore demands that the vessels they engage is as well.

11 Theory

11.1 Barriers

If an equipment or technical system is found critical should, according to the Code, the Company establish specific measures to promote the reliability. These measures can be several things, for example training, procedures and design, but in general will we be talking about a barrier designed to prevent or imitate the hazardous event.

A safety barrier is a physical and/or nonphysical means planned to prevent, control, or mitigate undesired events or accidents (Rausand, 2011, s. 364). A barrier may be integrated in two different ways, either as a proactive barrier that aims to reduce the probability of a hazardous event or as a reactive barrier that aims to avoid or reduce the consequences of a hazardous event.

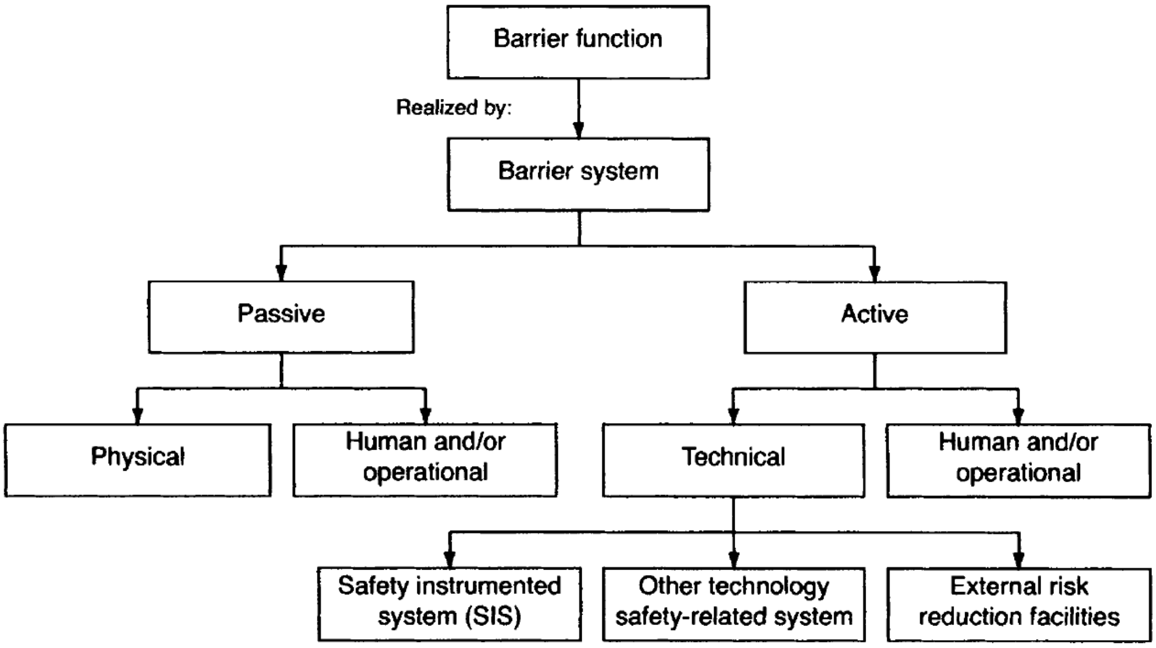

Figure 4- Classification of barriers (Rausand, 2011)

The figure above illustrates a possible classification of barriers. This method is based on Snorre Sklet's classification and states that the barrier system is either passive or active, and each of those can be either physical/technical or human/operational. A passive system is a barrier that has been integrated into the design of the equipment or technical system and does not demand any input to perform the barrier function. Examples might be watertight bulkheads, fire-retardant insulation or a railing, which all are physical barriers. An active system however, needs some sort of input, either from a sensor, from human actions or from an energy source to be able to perform the barrier function. Examples of such systems are fire alarms, emergency shutdown systems and bilge pump systems. All of these three examples of barriers that might be designed with sensors that automatically activates them, or with a button for human interaction.

James Reason, a psychologist that taken the roles of researcher, lecturer, reader, professor and author over the years with focus on human errors and organizational processes (safetyleaders.org) had another approach and classified barriers according to their purpose (Rausand, 2011, s. 368):

a. Create understanding and awareness of local hazards.
b. Give clear guidance on how to operate safely.
c. Provide alarms and warnings when danger is imminent.
d. Restore the system to a safe state in an off-normal situation.
e. Interpose safety barriers between the hazards and the potential losses.
f. Contain and eliminate the hazard should they escape this barrier.
g. Provide the means of escape and rescue should hazard containment fail.

The ARAMIS (Rausand, 2011, s. 368) was a European project that was carried out in support of the EU major accident hazard directive. A part of this is a classification that divides the barriers into four categories:

a. Avoidance: removing all potential causes of accidents by changing the design.
b. Prevention: accomplished by reducing the probability of a hazardous event or by reducing its consequences.
c. Control: limiting deviations from the normal and also delimiting emergency situations.
d. Protection: protecting assets from the consequences of a hazardous event.

These are three methods of classification of barriers, but there are several more available to choose from if these is not suitable for the given analysis.

For this thesis, the classification of James Reason is found most suitable for analysis of systems/equipment onboard vessels. This as it presumably will be easier to understand for a large group of mariners with different positions and backgrounds. If the leader of the toolbox meeting explains what kind of barriers that is available during the forthcoming operation and what is not, may he have a tool to provide a notice to the worker on what they may expect, or not expect, of warnings and when they have to think or act for themselves. There is nothing wrong with the other classifications and they may all suit this type of analysis, but they might not be in a way one can expect all masters, ratings, trainees, external readers and office employees to understand fully since all will have so different backgrounds and events to relate the information to.

An interesting part here is that some of the systems/equipment that will be analyzed is a barrier itself. A Fast Rescue Craft (FRC) and corresponding davit is an aid to evacuation and is therefore a reactive barrier installed to reduce the consequences of a hazardous event. In contrast to the reactive barriers is there also several proactive barriers installed to prevent the hazardous situation. The ECDIS may be an example of such. It is an aid to navigation and anti-collision tool that if operated correctly, may prevent grounding, collision or passage in dangerous waters. It has also features that make it a reactive barrier in search and

Regulations and laws are also barriers. Some will state what shall be done to avoid hazardous situations and others will demand systems or measures to reduce the consequence. This appears clearly in maritime context as all great accidents also brings a new regulation. After the Titanic accident in 1912 was several weaknesses in construction and operation discovered, which then was formed into what we today know as the SOLAS (Safety Of Life At Sea) convention. This was a major improvement of maritime safety policy, but other accidents since them has also contributed to new regulations both national and international. These regulations has to be treated as living since new technology, new demands and new ways to work will show new challenges and possible shortcuts.

The ISM Code 10.3 is a proactive barrier as it demands an identification of the critical systems/equipment which will arise awareness and precaution in handling those. The reference to SMS and regular testing of stand-by systems/equipment will also lover the chance of a hazardous situation. The focus on the equipment and technical systems used in hazardous operations is raised and precautions can be taken in advance.

The chain of event and some barriers may be affected by factors that might support the consequence or the barrier. For example will a leakage that occurs in a contained space where it have no way to end up in the ocean have a lower consequence than a leakage that goes directly into the sea. Icing and cold temperatures in the high north might also be such factor. The interesting is that it may both be a positive and a negative barrier. Negative as many materials turns more crisp as they are cooled down, but positive as high temperature is a requirement for a fire. Oil and other liquid material will flow slower and get a higher viscosity at cold temperatures, which will make it harder to leak and easier to gather up in case of a leakage.

11.2 Threat agents and human behavior

A threat agent is an individual or group of individuals that may present a threat. This agent may be an employee that intentionally take action to hurt or damage property or live objects (Owasp.org, 2012). In this thesis, however, is crew that unintentionally react on a new situation in a wrong way more appropriate definition.

Weather, temperature and natural disasters will be threat agents that is impossible to eliminate. Today's meteorological technology and mapping of weather supply the masters with a much better prediction than earlier days so that the forecast can be a part of the decision of how to work. If a heavy storm is expected shall the master consider whether this might lead to a hazardous operation or not and if he then should refuse to leave harbor or safe haven.

To eliminate the possibility of human error must one remove the human itself. More and more operations can be remote controlled or performed by robots, but human interaction and logic thoughts is still required to operate safely. Therefore is it not possible to eliminate the threat agent the crew constitute, but there are several way to reduce their influence in a hazardous situation. One of this is continuous training with equipment both on the vessel and at training centers. All seafarers is required to hold a course certificate which documents that they have been given an introduction to firefighting, personal safety and evacuation possibilities before embarking. This course provides them knowledge in a safe atmosphere where they are allowed to try and fail, as well as ask all the questions they might have. In a real situation is failing out of the question and one has to take necessary action in advance to make sure that the crew can function as needed when the bell rings.

For the firefighters is it important to train on their roles on board the vessel. They might know their way around the corridors in normal conditions, but will they be able to do the same when the light is out or the superstructure starts filling with black smoke? Such training on emergencies will have a positive effect on the performance of the crew when the real emergency strikes.

One thing is to train and prepare on what may be expected, but preparing for the unexpected is a lot worse. All human beings has their own way to react and cope with unforeseen events and they might not know themselves how they will respond before they are in the middle of it. The reactions might origin in previous experience, understanding of the situation, familiarity with system/equipment and of course instinct. "Fight or fly" is a common saying which reflects to whether the person will stay and mitigate the consequences or leave the scene to protect himself.

Surely, if the situation is hazardous enough will fighting be a bad decision, but rational thoughts might not get heard when instinct takes charge. Because of this is it impossible to know if human interaction will influence the event in a positive or negative way.

It is reasonably to say that every engineered system eventually will fail, but that is a fact for the human behavior as well. One can never know in advance exactly how a person will perform in a normal situation, in a situation where something unexpected occurs and least of all in an emergency.

Such factors is too diverse and dependent on the specific individual so concluding on an outcome will be impossible. Some reactions can be included, such as common human instincts to avoid hazard. These might include that all crew will back away from a fire and not walk through it, they will grab on to the closest object if they lose balance or react randomly if present to a trauma.

Such instincts will for example be beneficiary to analyze before designing the workplace or in preparation of a procedure. If the workplace is designed so that the most reachable object close to the open deck that easily can become slippery is an emergency break or a control unit may the outcomes most definitely have another outcome than it would with a more though through design.

Rausand (2011, s. 134) states three main strategies used to control and avoid human errors:

a. Error reduction: This involves designing the system to help the user avoid errors or correct errors that have just been made.
b. Error capturing: The intent of this strategy is to “capture” the error before any adverse consequences of the error are felt. An example of an error-capturing strategy is supervision and third-party checking of the task.
c. Error tolerance: This refers to the ability of a system to accept an error without serious consequences.

An error reduction strategy can be highly visible labeling of buttons, buttons that can be operated with gloves on, clear instructions that describes how to operate the equipment or technical system, or placing a rescue net on the sides of the gangway. Other than the example above can closed loop communication on bridge be an error capturing strategy where the sender can correct if the message is read back to him with a different meaning. Error tolerance strategy on board a vessel can be monitoring water content in the oil. The oil should be entirely clean and without water, but the system can operate perfectly as long as the content of water is under a certain level. This is monitored with sensors that send information to the engine control room or by periodically sampling or oil.

11.3 The risk acceptance criteria

It is important to establish a risk acceptance criteria early in the analysis process. The criteria will help to adjust the method of analysis for the specific equipment or technical system.

A regular PSV will in normal operation experience sailing in shore distant routes, for example transit Norway-UK, Europe-America or even the planned 243 nautical miles to the northernmost block in the Barents Sea. These are all areas with no or little aid of assistance in close vicinity and the vessel will therefore need to be their own police, fire brigade and ambulance. The crew is trained for those tasks, both from training on board and from course centers, but they are primarily mariners and cannot be expected to perform in the same degree as an educated police office, firefighter or surgeon does in their field of work. A fire brigade on shore will have the opportunity to return to their station to collect specialized equipment and for the medics to get hold of a large variety of drugs as well as getting the patient quickly on the operating table, all which is not possible several miles outside the coast. The vessel will carry the necessary and law regulated equipment to handle these situations, but one has to notice that there is limited space on board and that they have no means available to be prepared for every possible scenario.

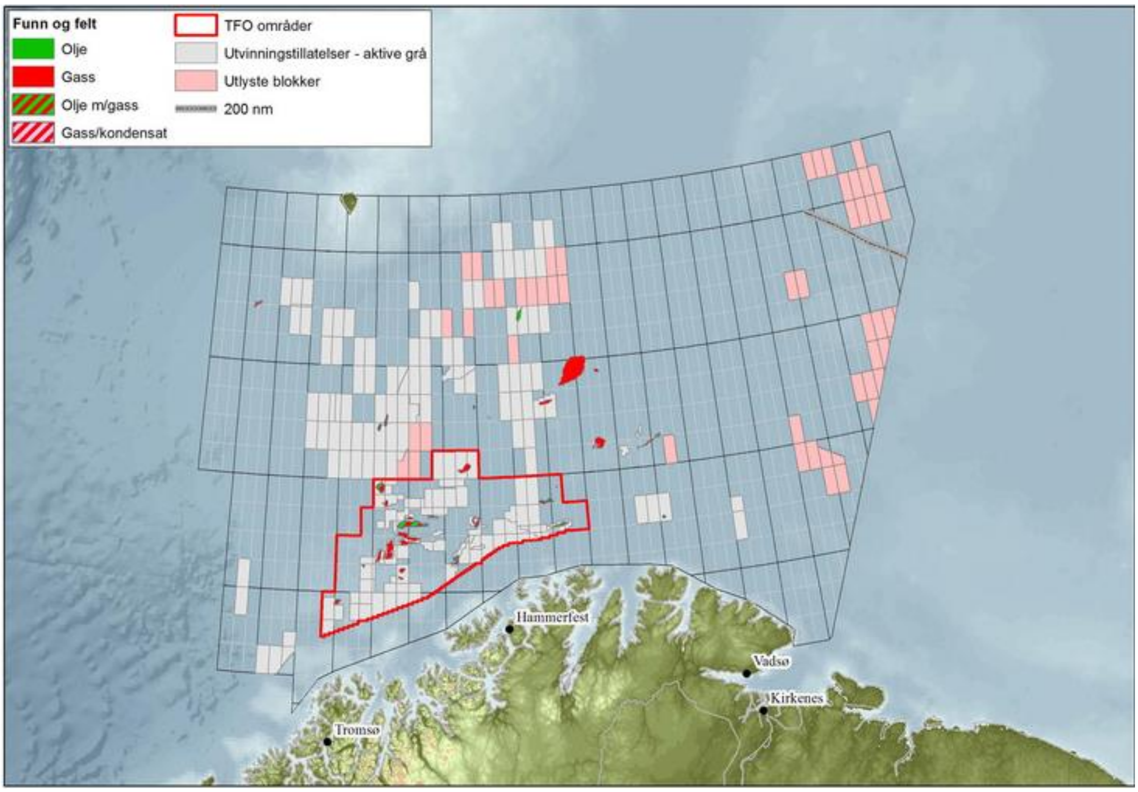

Figure 5- Map of new blocks in the Barents Sea (Teknisk Ukeblad, 2015)

This will strengthen the necessity of not having the need for this type of equipment or technical system; ergo avoid fire and all medical cases. Such goal is not realistic to achieve and directly dangerous to plan with. Therefore should one plan the equipment and training on board so that the most critical cases is dealt with by what one has present on board, but also take action to minimize the frequency and/or consequences of such events.

The ISM Code 10.3 says "...which may result in hazardous situation." , which opens up the possibility to connect the risk acceptance criteria and the hazardous situation so that the criteria is that a hazardous situation is not acceptable which again shall be the definition of critical equipment/system. For this thesis, is the definition formulated as:

A hazardous situation is an event that directly or indirectly can lead to physical or psychological trauma to a person that is directly or indirectly present, or be a threat to the environment.

This might sound a bit vague since as it covers indirect cases as well, but this is necessary to achieve a thorough analysis that will suit the vessel segment. A minor explosion might be of direct danger to the crew standing close, but parts might fly away with great force and break loose parts of the vessel construction. These parts might fall onto a crew standing in great distance from the explosion itself, but he might then become indirectly traumatized by the event to which he is not directly present. It is not possible to imagine every possible indirect outcome of any event, but some situation will be quite clear and therefore necessary to mention in the analysis.

Environment and assets should of course not be threatened either, but they must always be prioritized below the well-being of a person. NORSOK Z-008 (NORSOK Standard, 2001, p.11) demonstrates the below table as a minimum for classification.

Class	Health, safety and environment (HSE)	Production	Cost (exclusive production loss)
High	When substance is: • Hydrocarbons (highly ignitable gases and unstabilized oil) and other flammable media. • Liquid/steam, exceeding 50 °C or 10 bar. • Toxic gas and fluids. • Chemicals (see B.1)	As for production, class 'High' in Table 1.	As for cost, class 'High' in Table 1.
Med.	When substance is: • Stabilised oil, diesel and other less ignitable gases and fluids. • Liquid/steam, less than 50 °C and 10 bar • Toxic substance, small volume. • Diesel	As for production, class 'Medium' in Table 1.	As for cost, class 'Medium' in Table 1.
Low	When substance is: • Non-ignitable media. • Atmospheric gasses and fluids harmless to humans and environment. • Negligible toxic effects. • Harmless chemicals (see B.1).	As for production, class 'Low' in Table 1.	As for cost, class 'Low' in Table 1.

Figure 6- Consequence classification for containment (NORSOK Z-008, 2001)

This criterion is reasonable to use on all vessel, but it might then be stricter than necessary. If the vessel is a ferry that is a couple of miles off the coast at max will there be possible to lower the criteria. Such vessels will not use much time on getting to port, helicopters will always reach them and they will be designed in a different way as they carry passengers.

NORSOK Z-008 demonstrates the below table as a minimum when defining the consequence class. Stricter demands is always allowed and this is where the type of vessel and other factors will be important to evaluate.

Class	Health, safety and environment (HSE)	Production	Cost (exclusive production loss)
High	Potential for serious personnel injuries. Render safety critical systems inoperable. Potential for fire in classified areas. Potential for large pollution.	Stop in production/significant reduced rate of production exceeding X hours (specify duration) within a defined period of time.	Substantial cost - exceeding Y NOK (specify cost limit)
Med.	Potential for injuries requiring medical treatment. Limited effect on safety systems. No potential for fire in classified areas. Potential for moderate pollution.	Brief stop in production/reduced rate of production lasting less than X hours (specify duration) within a defined period of time.	Moderate cost between Z – Y NOK (specify cost limits)
Low	No potential for injuries. No potential for fire or effect on safety systems. No potential for pollution (specify limit)	No effect on production within a defined period of time.	Insignificant cost less than Z NOK (specify cost limit)

Figure 7- General consequence classification (NORSOK Z-008, 2001)

11.4 How to identify the best method

Describing a good method of analysis will often include a lot of opinions and preferences based on experience, as well as numerous demands due to application. Some commonalities is still found, for example listed in the Research Methods Knowledge Base (Trochim, 2006) where credibility, transferability, dependability and confirmability is the key words to obtaining qualitative validity in a method. Due to the lack of numeric values as information on the equipment and technical system will these methods be qualitative analysis of those.

11.4.1 Credibility

The users must feel comfortable with the method, believe that it is able to always perform as intended and they must be able to understand it. They will not be able to judge if a method can perform unless they are able to understand what the method does. Since the crew on the vessels have a great variety in methodical knowledge should the method be designed intuitive and with enough description to keep everyone on board. If there is too much information may the weakest give up and the strongest take it less serious. The wording weak and strong does not refer to intelligence, but rather to the ability and drive to obtain information.

11.4.2 Transferability

The method must be usable on any kind of equipment and technical system on any vessel. In this case is it crucial that the method is able to discover weaknesses, mark connecting equipment or technical systems, is able to use the standardized setup and come to the same type of conclusion no matter how simple or complex the given equipment or technical system is.

11.4.3 Dependability

The method must be able to detect the same hazardous situation if two or more independent persons is performing the analysis at different times. It needs to be so correctly templated that there is only one way to move forward, given that those performing the analysis may be found equal in terms of competence and knowledge about the equipment or technical system.

11.4.4 Confirmability

The method must have room for enough information to enable confirmation from several users. The result must be documented and described so that all can see what the decision is based on in order to agree or disagree on the judgement. If this information is not present, will occasional mistakes be invisible and nobody other than the author will feel ownership to the analysis.

If all the above has been achieved may the method be on its way to perfection, but is perfection possible to reach or will the different characteristics inhibit each other?

The best method includes all possible situations, settings and consequences no matter how unlikely they are. It considers the effect of a failure in every component of the system and reflects on all reactions to the event. Realistically is this difficult to achieve. Such analysis will also become too heavy and theoretical for the intended users. They are mainly interested in whether the system/equipment is critical or not and perhaps if the consequences can be eliminated or reduced. Only in special situations will there be a need for such detailed analysis and performing it on a regular basis will cost more than will be gained. Take for example the fault tree analysis, described in 11.6.3, which have the potential to grow to infinity and be unreadable for the average person. One should therefore evaluate the different cases to determine which of the criteria that needs to be considered most important if satisfying all is not an option.

Winston S. Churchill once said that "A good speech should be like a woman's skirt; long enough to cover the subject and short enough to create interest". This quote is highly accurate when it comes to analysis that will have a practical matter to the user. The analysis must contain enough details achieve the full understanding, but not too detailed either so that the reader loses the grip of the situation or stops reading and give up. If they have to search for explanations and description on how to understand the analysis in advance is the chances present that they will put it aside and hope for success.

11.5 Analysis methods

In general can all analyses be divided into two groups: qualitative or quantitative. Which type to use, if not a combination, will depend on the subject to be analyzed, available information on the subject, the readers, where in the "process" one is at the point of analysis etc.

11.5.1 Qualitative analysis

A qualitative analysis emphasizes the understanding and analysis of relations in a process, often in order to understand how an individual feels and thinks. How and why will be essential question to answer in such analysis.

William M. K. Trochim describes four out of many qualitative methods available: participant observation, direct observation, unstructured interviewing and case study (Trochim, 2006). A participant observation is one of the most common methods for qualitative data where the researcher becomes a participant in the culture or context he analyzes. In a direct observation will the researcher not include himself as a participant, but rather observe the phenomena. Scientists observing animal interaction from behind a one way mirror is one example of this method. Unstructured interviewing will be sort of a conversation interview where the researcher can follow up comments without striving to follow a planned list of questions. This may be harder than structured interviews as the amount of data is unknown in beforehand and the analyze can be difficult as one may not have the possibility to cross check answers between study objects.

This thesis is an example of a quantitative case study as it strives to study a specific context. There is no specific way of conducting a case study and a combination of the above methods or others can be used.

11.5.2 Quantitative analysis

A quantitative analysis is based on variables expressed with numeral values. For example may a statement be that "nine percent of all vessels will run aground in a period of ten years" or "the consequence is 75 on a scale from 0 to 100, ergo critical". Numbers is a good way to get people to understand the message, especially when the end number indicates a score on a given scale, but a majority of the important information describing the surrounding settings may get lost.

Such type of method is almost impossible to use for the analysis this thesis seeks as the systems often consists of several subsystems or equipment that has their own risk of failure. Many of these numbers does not exist or the suppliers may refuse to distribute them according to company policies. It is definitely possible to test the systems and equipment, but when they fail one will have the cost of replacing them. In addition, will this also take a lot of time and therefore also not be an efficient method.

How likely an equipment is to fail is also time dependent as shown in the bathtub curve below. The age and amount of ware needs to be logged at all times. Age is ok, but how shall the amount of wear be defined in a way everyone understands and can follow up?

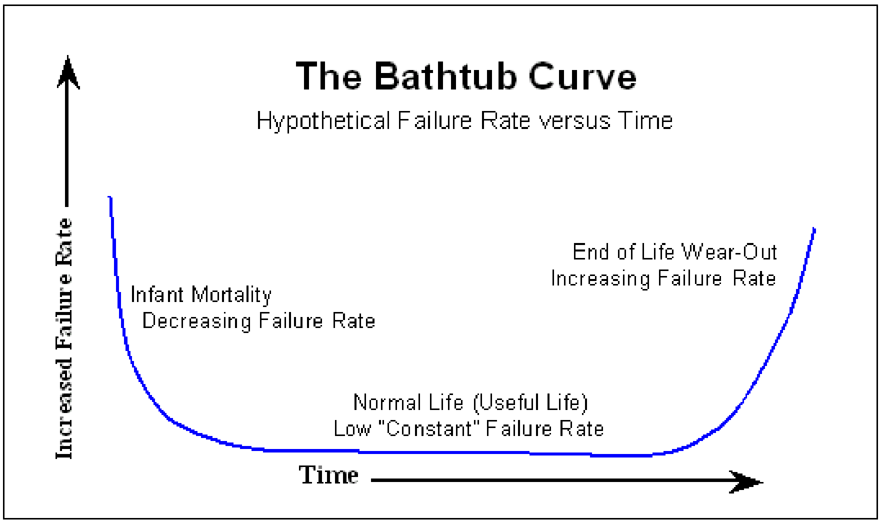

Figure 8- The Bathtub Curve (Wilkins, n.d.)

Other factors such as temperature, maintenance, correct/incorrect operation and external forces may be hard to define the significance of and this may be a severe factor of error.

If one manage to find a number for the system's ability to fail, one will also meet the same challenges when then trying to set numbers on what may happen next and finally gather all this into a total number that shall determine whether this is a hazardous situation on not. The systems on a modern PSV will simply be too complex to handle.

Even if one wanted to try, it will be hard to complete as the majority of the numbers needed is unavailable. The components, equipment and technical systems has in general not been tested enough to satisfy this need. In addition, as mentioned above, will the number have a large variety based on several external factors.

DNV GL (2016) states that a Quantitative Risk Analysis is a formal and systematic approach to estimating the likelihood and consequences of hazardous events, and expressing the results quantitatively as risk to people, the environment or your business.

The QRA will generally be used to answer what can go wrong, how likely is this event and what are the consequences if such event takes place. After assigning numbers to each of those elements is it possible to calculate the risk as a function.

11.6 Example methods to be evaluated

11.6.1 Introduction

Over the next chapters will five different methods be introduced and later used to analyze the chosen equipment or technical system. The first three methods is commonly used methods in risk and reliability studies, and the last two designed with the purpose of satisfying the ISM 10.3.

Pros and cons with the different methods will be presented in the thesis, but some comments might be removed from the information distributed to the expert panel in order to not guide them in any directions. The fact that the author has designed one of the methods will also be hidden as the author has communicated and met several of the experts through her daily employment. Real, honest and constructive feedback is wanted and this might interfere with the expert's attitude towards the method.

Figure 9- Troms Arcturus (Shipspotting, 2014)

11.6.2 FMECA

The Failure Mode, Effect and Criticality Analysis is a technique used to identify, prioritize and eliminate potential failures in a system, design or process (Haugen & Rausand, n.d.) It is often used as a precautionary analysis to identify weak systems or equipment in the design phase in order to improve them before they are taken into use.

An FMECA is mainly a qualitative analysis and should be carried out by the designers during the design stage of a system. The purpose is to identify design areas where improvements are needed to meet reliability requirements. An updated FMECA is an important basis for design reviews and inspections (Markeset, 2013, p. 23).

The ISM 10.3 relates to equipment and technical systems that are already in use or ordered to be installed. An FMECA should in other words already have been performed before those are fitted and the report show a trace of what improvements that have been initiated. The FMECA will also strive to display ways to detect the failure, which in the case of a vessel and the Code is not an issue as it will be too late to take precaution when the failure is detected.

The criticality part of the FMECA is based on the consequence level and the history of such event. If it shows that the failure of a specific component will lead to great consequences and has a record of failing often, is this a good indication that this part should be replaced by another option that scores lower on one or both points.

An FMECA with a specialized worksheet may adapt ok to be an analysis that satisfies 10.3. It may be used on all equipment and technical systems, it is possible to use it on another PSV, it will definitely identify weaknesses in the equipment and technical system as well as containing lots of information on the system, but it is likely to be too theoretically tough to be useful for all intended readers. The trainees on board are the crew with lowest rank on board and they have typically two year high school as their education. This is adequate according to the job they are learning and they have all great minds, but reading and fully understanding the text that a FMECA will produce can in general not be expected of them.

The analysis is executed according to the following scheme ((Rausand, 2004) as cited in Markeset, 2013, p. 23):

1. Definition and delimitation of the system
2. Definition of the main functions of the system
3. Description of the operational modes of the system
4. System breakdown into subsystems that can be handled effectively
5. Review of system functional diagrams and drawings to determine interrelationships between the various subsystems.
6. Preparation of a complete component list for each subsystem
7. Description of the operational and environmental stresses that may affect the system and its operation

System: FRC Davit Troms Arcturus						Performed by: Signy Anita Løvmo					
Ref Drawing:						Date:					
Description of unit			Description of failure			Effect of failure					
Ref No	Function	Operational Mode	Failure mode	Failure cause or mechanism	Detection of failure	On the Subsystem	On the system function	Failure rate	Severity ranking	Risk reducing measures	Comments
SFI 501.10.01	Safely lower and raise the FRC	Lower, rise, standby, test.	Moves uncontrolled	Broken wire, signal fail in remote, load limit exceded, brake fail	Inspection or in operation	Physical damage to FRC	System does not perform as expected, system might get further damage.	Unknown	Catastrophic	Inspection, maintenance, procedures for launching the FRC	If the davit fails may crew get injured and evacuation /SAR/ transportati on/ collection/ inspection inhibited.
			Does not move	Oxydation, brake fail, ice, power break	Inspection or in operation	FRC can not perform as intended	Whole system not functioning.	Unknown	Catastrophic	Inspection, maintenance, extra power supply, heating	

Figure 10- FMECA flowchart (Løvmo, 2016)

11.6.3 Fault three analysis

The most common method for risk and reliability studies today is the Fault Tree Analysis. It was invented in 1962 by Bell Telephone Laboratories and later improved by the Boeing Company that also introduced computer programs that could handle both quantitative and qualitative FTAs. The analysis will result in a diagram that displays the interrelationship between a potential critical event and its cause (Rausand & Høyland as cited in Markeset, 2013, p. 26).The problem is that this analysis is quite narrow. Since the method is used in the design phase is not the bigger picture with people and assets completely integrated.

An FTA is normally carried out in five steps (Rausand & Høyland as cited in Markeset, 2013, p. 26):

1. Define the issue and the boundary conditions of the system you wish to analyze.
2. Construct a fault tree.
3. Identify minimal cut and/or path sets.
4. Perform a qualitative analyze of the fault tree.
5. Perform a quantitative analyze of the fault tree.

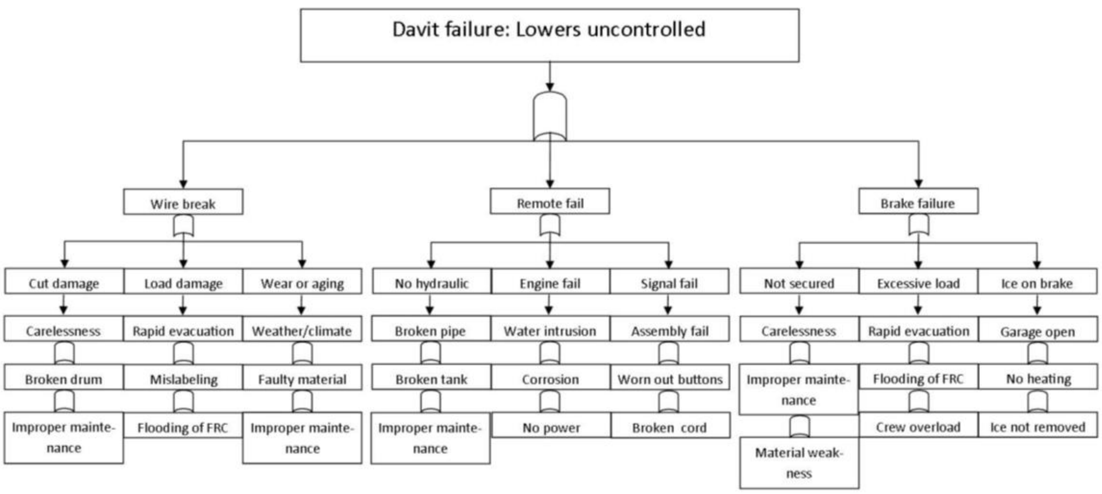

Figure 11- FTA flowsheet (Løvmo, 2016)

Above is a simple way to illustrate a FTA shown. We see the top event, as a reaction to three different events. It may in real life certainly be more than three events, but these three has been chose to illustrate how the analysis is carried out.

Each of those three events will be initiated by three main causes, which all occur as a result of three triggering factors. Notice the OR gate, this indicates that the triggering factors must not all occur at the same time in order to create the main cause. Only one is necessary to initiate the event, but if more than one occur will the result have the potential to be even more destructive.

One can in theory include all possible causes for an event following all their possible causes and so on. It can therefore be wise to plan a limit before conducting the FTA.

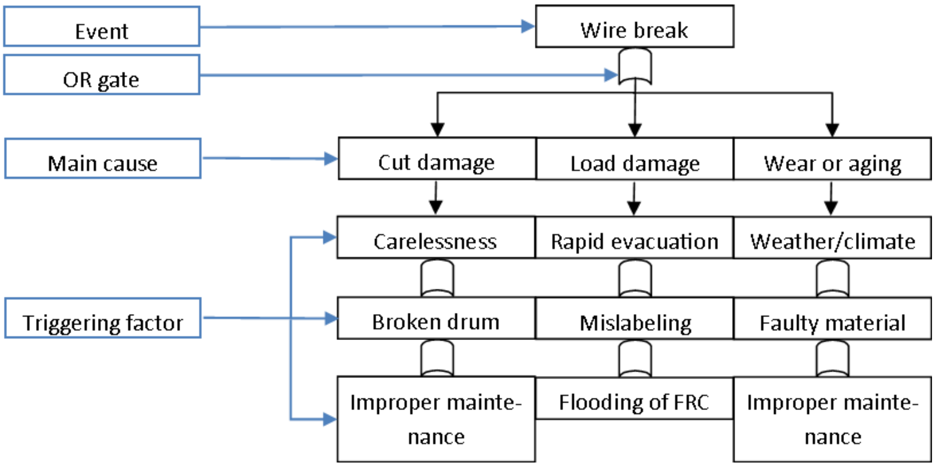

Figure 12- FTA with explanatory notes (Løvmo, 2016)

In case the description was misleading may the above illustration name the different parts. The black is a cut out from the complete flowchart and the blue field are explanatory notes.

For this thesis has only the OR gate been used, but there are several other gates that can be used in an FTA. The Figure 13- FTA Diagram symbols (Conseptdraw, n.d.)Figure 12- FTA with explanatory notes (Løvmo, 2016) displays some of these and such overview shall be attached to the analysis to avoid misunderstandings.

We find the transfer symbol there that can mark a connection with a sub tree, which could be an option when large equipment and technical systems has the possibility to split into sub systems. In that way may each diagram be smaller and easier to read and interpret.

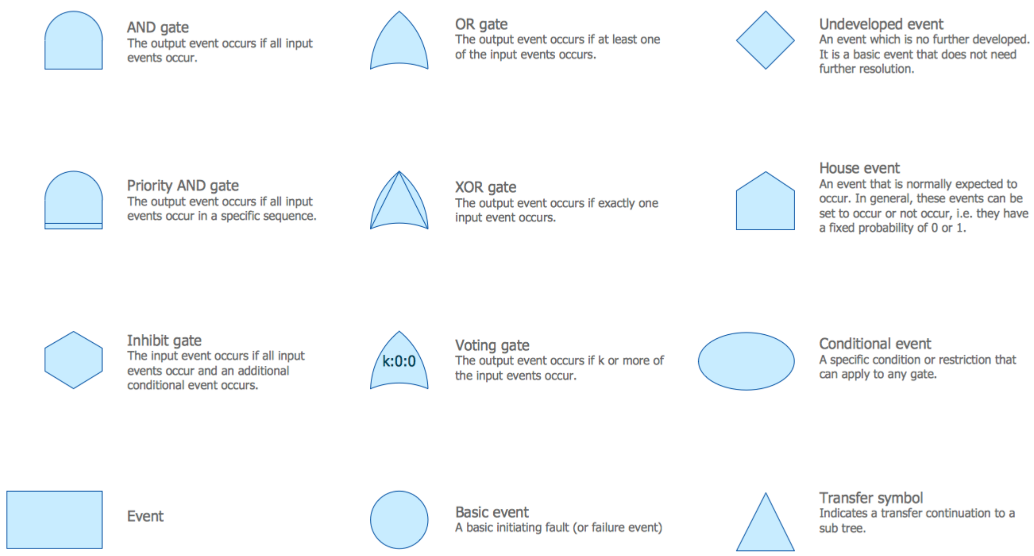

Figure 13- FTA Diagram symbols (Conseptdraw, n.d.)

11.6.4 Event tree analysis

The ETA analysis starts at the initiating event, and then demonstrate the possible outcomes. One of the benefits with this analysis is that it includes the barriers that may stop or mitigate the chain of events. The ETA is commonly used in the design phase to visualize the effect of different barriers and showing the different chain of event that forms when the barrier is function or not.

The analysis is often carried out in six steps (Rausand & Høyland as cited in Markeset, 2013, p. 32):

1. Identification of a relevant initiating (accidental) event that may give rise to unwanted consequences
2. Identification of the safety functions that are designed to deal with the initiating event
3. Construction of the event tree
4. Description of the resulting accident event sequence
5. Calculation of probabilities/frequencies for the identified consequences
6. Compilation and presentation of the results from the analysis

The critical event, or initiating event as it also may be called, will form the base for the entire analysis and must therefore be chosen correctly. Rausand & Høyland ((2004) as cited in Markeset, 2013, p. 32) defines the initiating event as "The first significant deviation from the normal situation that may lead to a system failure or an accident.". Thinking through exactly what this event is before starting the analysis itself is therefore necessary. There may often be several correct initiating events in the same case, but one of them is likely to result in a tree that really highlights the barriers and not draw attention the wrong way.

Paragraph 1 is also a question whether the analysis is necessary or not. If one cannot find any unwanted consequences is the analysis unenforceable and other types of analysis may be chosen instead to confirm that the equipment or technical system is safe.

The barriers will be any aid intended to stop or mitigate the initiating event to lead to a consequence that is critical in any degree. Both barriers that will limit the event and those protecting the surroundings is important. In the ETA shall all barriers, of any kind, that may have any effect be identified and listed in the order they will activate. Barriers that are installed, but do not hold any power to work on the given event shall be neglected. For a pipe system with several valves and vents down the line will this be relatively easy, but more complex systems may require a more thorough explanation.

As shown in 12.1.6.3 is the ETA visualizing the progression starting with the initiating event and then proceeding by splitting into TRUE or FALSE for every barrier indicating the situation if the barrier works or not. There are no specific rules about this, but the common way is to draw the tree from left to right and that the above branch at each barrier is the true event. A trick is to plan how the chain is listed so that the worst consequence is always on top. This will result in a descending list of possible outcomes that will be easier for all to understand. When planning the form will barriers that have no effect on the event be easy to spot as they will never be “false”.

This ranking may be used when describing the different parts of the ETA afterwards. Some chains will end up in, or close to, normal function while others end up as catastrophic. Chains that don’t end in hazardous consequences may be barely mentioned, but those that are critical require a more thorough yet easy to read walkthrough. This way of thinking will result in a report that shows logic between text and visualization.

The explained method is the qualitative ETA that uses wording to describe the possible outcomes and barriers. In some cases is it favorable to know the frequencies and probability of these so that a quantitative ETA is to prefer. The mathematical term of such analysis will not be mentioned here, but it is clear that knowledge in probability calculations is required to perform this analysis. One case is that this might limit the group that will perform the analysis itself, but I may also make it harder to provide a fully understandable analysis for all the intended readers when those are mariners. When analyzing equipment and technical systems on a modern PSV may one discover that they are very complex and connected to each other in multiple ways. All this, combined with the large number of assumptions one has to do where no data is available makes this side of the method worth neglecting.

11.6.5 The B. Apperry method

The three methods that have been presented is quite general and may be used in several different settings. It would be very interesting to find methods that is in use and relates directly to the ISM 10.3. This search has been however fruitless. A probable explanation is that preparing an analysis is quite a job in itself and several ship owners modify methods to fit their vessels and national rules in the best way. Therefore is it possible that they are not very willing to share their results and methods with others, especially not online. Using another ship owners methods may also be of certain risk without performing a careful analysis of it in advance. As stated in 11.3 may the risk acceptance criteria differ between different vessel types and trade areas, so approving someone else’s work in such an important case must not be looked upon lightly.

One method that did show up was this designed by Bertrand Apperry (Afcan, 2007). The pages leading to this method site is in French and designed in a way that do not allow any translation other than word by word. There has not been used extra time to perform this translation so the background check of the site is somewhat inadequate. The overall impression is that the site publishes discussions and text on different maritime laws and regulations.

Appery is a member of the International Institute of Marine Surveying with “General and container cargoes”- and “State or government” surveys as his field of expertise (IMS, n.d.). He wrote his article in 2007 as a result of his experiences as a master mariner and discussing the ISM 10.3 with his colleagues. He had then been at sea for most his life, of which more than 20 years as master mariner.

Firstly, Appery define that these groups of apparatus or systems are required to perform when the vessel is in operation:

- Propulsion, navigation and their management
- Port operations; manoeuver and commercial operations
- Power and its management
- Permanent safety; detection, lighting and eventually automatic fire extinction
- Response elements; extinction, fire or drainage pumps
- Survival; abandon, search and rescue

Secondly, he defines: “If this apparatus or system stops of working (breakdown) or cannot be used (does not start or is in such bad condition preventing it from ensuring its role) either this unavailability is unlikely to put anybody in danger : that is a non critical equipment, or there is a risk and it is the responsibility of the SMS to ensure the safety of the persons on board, the ship itself and the environmental protection: we have there a critical equipment”.

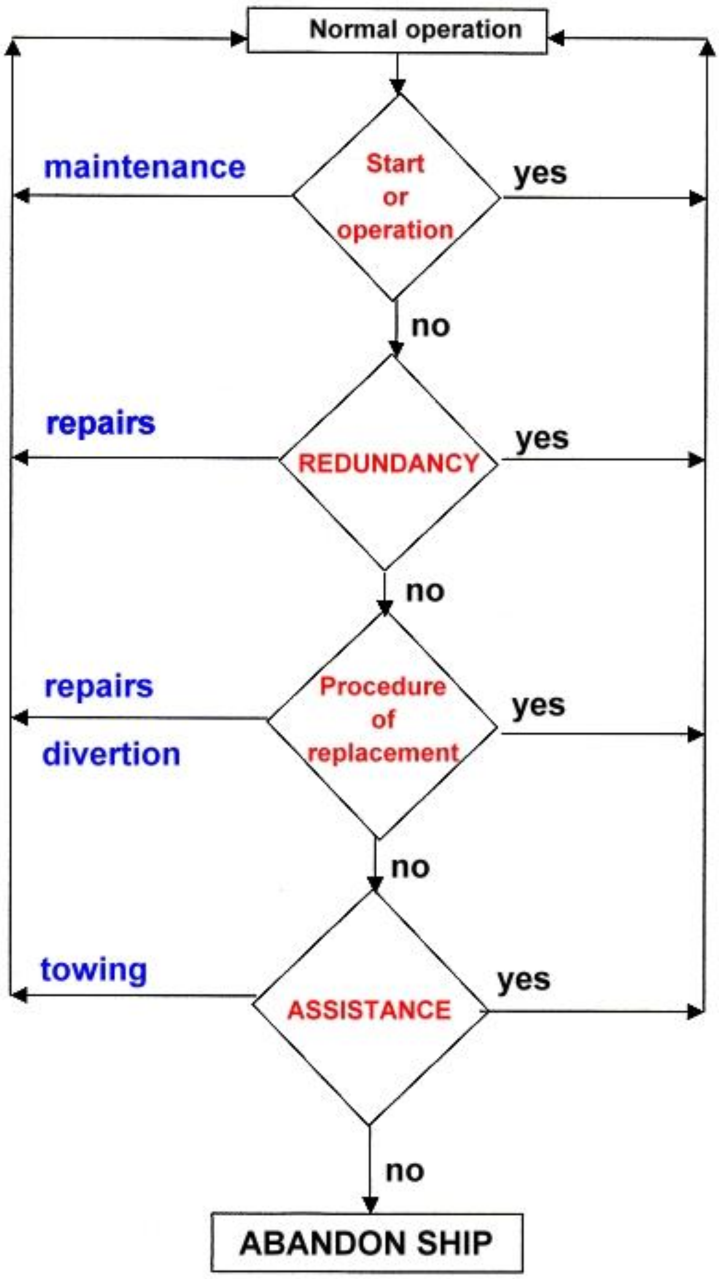

Figure 14- Apperry's operation flowchart (Afcan, 2007)

Appery chose to rank the level of criticality based on which measures that is initiated to ensure the safe operation of the given equipment or technical system.

- Critical without redundancy nor procedures of replacement
- Critical with procedure of replacement
- Critical with redundancy
- Critical with redundancy and procedure of replacement

- Not critical

Doing this will make it visible if an equipment or technical system breakdown will be a catastrophe in itself or if the vessel will be able to function satisfactorily, but not as designed.

Steps of the analysis:

1. Describe the equipment or technical system.
2. Determine the level of criticality
   - Critical without redundancy nor procedures of replacement
   - Critical with procedure of replacement
   - Critical with redundancy
   - Critical with redundancy and procedure of replacement
   - Not critical
3. Describe which specific measures that can be initiated to improve the reliability.
   - Automatic Power supply
   - Redundancy and/or replacement procedure
   - Reinforced maintenance or more frequent testing by ship's crew.
   - Periodical Control by specialized company.
   - Spare parts on board for a possible repair by the ship's crew.
   - Spare parts on board for a possible repair in the nearest shipyard.
   - Copies of the collection of drawings and plans in a safe place (including digital documents).
   - Familiarization and preparation of the ship's crew.
   - Special training of operators.
   - Experience feedback from Shipboard, Company or equipment builder.
4. Describe which replacement procedures that can be initiated to improve reliability.
   - Second line of command.
   - Hand drive operation on the spot.
   - Emergency power or fuel supply by derivation.
   - Emergency power supply in the event of partial or total blackout.
   - Emergency drainage by derivation.
5. Analyze risk and operation in a degraded status.

11.6.6 The authors method

In identifying a best suitable method, a new method is developed. The method is based on knowledge on other methods, such as the first three presented in this thesis, already established routines at TOAS and a maritime angulation, as well as consideration of the intended users and readers. Since the method will be revised by the mentioned expert panels will it from now be referred to as "The Ajabu method", which means "the great method" in Swahili. This, as well as a fake background story, is done in order to avoid the expert panels not speaking freely or criticizing this method. The author has during the two last years at TOAS been in contact with the majority, if not all, the experts and believes that they might treat the method differently if they knew it was designed by her.

As presented in FMECA, FTA and ETA is this method including a flowchart that will help visualize the analysis in a believed logical way. This in order to cover both the situations that only requires a quick answer whether the equipment or technical system is critical or not, and those situations that will require more details, information and "what if" discussions. That way will this method be useful for the trainee that is eager to understand the vessel as well as the master preparing an operation that will demand the outmost safety and reliability.

The Excel sheet have several similarities with the FMECA, but it is so specific for the purpose of satisfying the ISM that we can't just call it a modified FMECA. This method will in most cases not focus at the detection of failure as the FMECA does, but rather focus directly on the event that has happened no matter how and who detects it. The exception might be when the analyzed equipment or technical system is a detector of any kind.

The analysis step by step:

1. A brief introduction of the equipment or technical system.
   - Its technical details, purpose, how it is used, and applicable regulations and procedures.
2. Scenarios.
   - In what basic way(s) may the equipment or technical system fail, what conditions are set and additional description of the situation.
3. Consequences.
   - Which consequences may these scenario(s) lead to, in what way will this may affect other equipment and technical systems, will the hazard affect one or more persons

directly or indirectly, and other notes worth mentioning related to this event. Define the worst-case scenario for the given equipment or technical system.

4. Criteria.

- Which criteria has to be fulfilled in order for the initiating event to end up as the worst case scenario?

5. Evaluation of hazard.

- Is the worst-case scenario a hazardous event and is it impossible to entirely eliminate the criteria?

6. Barriers.

- What barriers is installed in order to inhibit the criteria? Will these barriers be possible to use without depriving the system/equipment/vessel its safe main function?

7. Evaluation of hazard.

- Is it possible to avoid the hazardous situation fully or reduce the risk to a minimum by these barriers? May customized maintenance in any way be able to stop the hazard without any barriers?

8. Additional information.

- Describe any information that do not fit naturally earlier in the analysis. Explain any assumptions or interpretations, if something is excluded from the analysis and why.

SFI Code	System/Equipment	Failure mode	Worst-case consequence	Criteria	Initial consequence level	Criticality	Barrier	Barrier effect	Barrier limitation	Final consequence level	Relevant procedures	Comments
501.10.01	FRC Davit	Lovers uncontrolled	Trauma or fatalities	Crew in FRC	Safety		None	None	There is no other access points to the FRC other than when hanging alongside in garage.			
					Environment		None					
				Persons under FRC	Safety		Procedures for securing area below FRC	If performed will criteria be eliminated.	Time and recources needed.			Not Infallible.
					Environment		None					
				Davit failure	Safety		Maintenance and inspection	Expand lifespan and safe operation	Will not inhibit aging, weather, wear etc.			
					Environment		None					
		Does not lover	Evacuation, SAR and transportation disabled	Evacuation needed	Safety		No crew on board, flooding pumps, fire inhibitors etc.	Inhibits evacuation need	Not able to eliminate all situations			
					Environment		None					
				Person or object in water	Safety		Railing, safety harness,	Reduce risk of falling into water	Human error, fault in equipment			
					Environment		None					
				Other means of evacuation available	Safety		Dacon Scoop, ladder, gangway etc.	Eliminate the need of FRC	Weather dependent, vessel not always in port			
					Environment		None					

Figure 15- Ajabu flowchart (Løvmo, 2016)

A color of green, yellow or red represents the consequence criticality both before and after the barrier. If one or more consequence before the barrier is red, shall one categorize the equipment or technical system as critical. It is extremely important to note that if the consequence after the barrier is green does this not in any way indicate an uncritical equipment or technical system, just that the criticality is observed and measures has been taken to improve the reliability.

A common risk matrix is based on the relationship between the likelihood of an event and the consequence of the event. In this case is the likelihood irrelevant as the analysis focuses on the consequences and possible chain reactions after the event has occurred, but the levels set in the TOAS risk matrix is a good base to work with.

The consequence level is defined as follows:

Green:

- No loss of live or trauma to people.
- No environmental damage.
- Economic loss < NOK 50.000,-.

Yellow:

- No loss of life. Potential trauma will not lead to a LTI, medical case or PTSD.
- Maximum emission of 500 liters of brine and/or 100 liters of oil.
- Economic loss < NOK 200.000,-.

Red:

- Potential loss of life, medical case, LTI or PTSD.
- Emission over 500 liters of brine and/or 100 liters of oil.
- Economic loss > NOK 200.000,-.

The trauma definitions is based upon the common medical practice in Norway and if a doctor is believed to send a patient away with or without treatment, or if a sick leave is expected. Different doctors will consider the illness different so it will be impossible to set an exact criterion to this. So will the difference in the ill person's rank be too; a navigator can perform his job safely if he has a broken toe or finger without any pain, but an AB that needs to use all his limbs actively when working will probably get a sick leave in order to avoid the bone growing back in an odd position.

The environmental damage requires that the leakage is located is a place where the spill has the potential to reach the sea. A small leakage in a closed area which is easily cleaned up and collected is no environmental damage, as well as a leakage into an oil drain.

The economic loss include both repair/replacement of failed equipment or technical system, following damage and loss of income. This shall not be considered when deciding the criticality unless economic loss is the only possible loss.

12 Performing analysis on chosen equipment or technical system

The methods presented in the previous chapter will now be processed by performing analysis of real equipment used on Arcturus. Choosing a system that is common on a PSV, although the model on Arcturus is unique in the TOAS fleet, is done to have information that is necessary for the analyses, but also to provide the expert panel something they can relate to.

Figure 16- MV Troms Arcturus (Skipsrevyen, 2014)

12.1 Fast Rescue Craft Davit

The equipment list of the vessel was revived and the FRC Davit chosen to be first out. The davit is a quite simple equipment that is thought to be understandable for a large audience as it is a modified version of something the majority has seen one way or another. Arcturus has a special type of davit compared to the other TOAS vessels as hers has a feature that enables a movement in lengthwise direction. This feature result in the FRC being safely placed in a closed garage when not in use. This is design developed especially for arctic waters where icing and temperature is threats to the equipment (Aukra maritime, n.d.).

12.1.1 General information

An FRC (Fast Rescue Craft) is a small vessel, typically under ten meters, that is commonly used for collecting objects from the sea or other tasks that requires a small vessel with good maneuverability and high speed.

Figure 17- Mare Safety GTC700-2VD (Mare Safety, n.d.)

The FRC Davit (hereafter davit) is located approximately amidships on Arcturus' port side in a garage. The davits task is to hold the FRC steady while not in use and to launch the FRC controlled when needed. One may look at it as a crane that is specially designed for this task. To launch the FRC the crew will lead the davit holding the FRC first in lengthwise direction to get into a position where the ships side below the FRC is as straight as possible, and then perpendicular to this motion to lead the FRC outside the shipside. Before this last motion shall a protection wall be lifted up and reveal a hole in the ships side for the FRC to get through. The wall's rupture strength is lower than the force the davit will use in the perpendicular motion. Therefore will the davit be able to break through the wall if this is stuck in any way.

The FRC is a Mare Safety GTC700-2VD with LOA of 7,18m and breadth 2,85m (maximum). It is produced in aluminum, weighs 2630kg and has a normal speed between 20 and 40 knots.

The davit is an Aukra Maritime AMTDT-3700 with a SWL of 3700kg and normal lifting/lowering speed of 0-50m/min. It can operate safely with a 20 degree list and 10 degree trim. The temperature range for safe operation is -20 to 40 degrees Celsius.

The davit will launch and retrieve the FRC when a hydraulic controlled winch is operated. This winch and the two drive gears used for traveling gets their hydraulic power from an integrated power pack that is mounted on the davit itself. To operate the davit may the crew choose between a control station and a remote (handle). The power pack consists of the tank containing fluid and an electric motor that drives the pump. For monitoring and safety is an oil level glass, breathe filter system, drain valve, full flow return filter and main safety pressure valve installed.

Brakes is also installed and they will be able to stop a fully loaded FRC combined with the dynamic forces that might be present if it starts falling. The brakes should also stop the FRC immediately if the hydraulic forces decrease as a result of a broken pipe or similar.

Figure 18- MOB and davit on Troms Pollux (Hansen, 2016)

The above picture illustrates another type of davit. Troms Pollux's MOB hangs in a railing that will move it straight sideway when operated. When not operated will the MOB hang as shown and kept still by the claw-like construction to the left in the picture. The protection wall to the right is the same type as found on Arcturus.

12.1.2 Practical example

Below is a practical example to illustrate the importance of a fully functioning davit.

If the Heidrun platform catches fire or becomes unstable may 230 persons be in need of immediate evacuation and rescue. Imagine all of these being launched into the sea by Heidrun's own skid launched lifeboats, but all these fails after hitting the sea surface and the people has to get into the water.

The SWL on the davit is 3700kg and the FRC itself weighs 2630kg fully equipped, which leaves us 1070kg for people on board. With immersion suits, warm clothes and some water is it fair to say that an average person weighs 90kg. This leads to 11-12 persons can be on board for every lift from the sea. Two or three of these will be crew so at the end can the FRC carry 8-9 evacuees. If Arcturus alone should perform this operation without risking anybody becoming unconscious due to the cold water, assuming all of them are in the water with immersion suits, the whole operation is allowed to take maximum 90 minutes.

Assuming lift/lowering speed to be 50 m/min, FRC moving in 30 knots and the distance between Arcturus and the platform to be 500 m (safety zone). Every pick up from sea to FRC takes 1 minute and the transfer from FRC to vessel takes 4 minutes. The distance from the sea surface up to the deck is 7 m and one knot is 1852 m/hour.

Number of collections= $\frac{\text{Number of evacuees}}{\text{evacuees per trip}} = \frac{230}{9} \approx 26$

Total time needed= Number of collections * (time needed from sea surface to garage + transfer from FRC to vessel+ time from vessel to/from evacuees)

$$= 26 * (\left(2 * \left(\frac{\frac{50\text{m}}{\text{s}}}{7\text{m} * 60} \right) \right) + 4 + (2 * 30 * \left(\frac{1852}{60} \right) / 500) \approx 206 \text{ min} \approx 3{,}5 \text{ h}$$

This proves that not only will the actions performed from Arcturus not be enough alone, but it is also clear that any kind of delays can affect the outcome negatively.

12.1.3 Davit analyzed by all methods

The FRC davit will now be analyzed by all the methods presented in 11.6. If a method only handles one scenario at the time may only one scenario be shown if this is sufficient to get the method demonstrated, preferably that the davit lowers the FRC uncontrolled.

Each method will start with a brief explanation and then move chronologically through the steps that is already listed for each method in 11.6 for the given method.

12.1.4 FMECA

System: FRC Davit Troms Arcturus						Performed by: Signy Anita Løvmo					
Ref Drawing:						Date:					
Description of unit			Description of failure			Effect of failure					
Ref No	Function	Operational Mode	Failure mode	Failure cause or mechanism	Detection of failure	On the Subsystem	On the system function	Failure rate	Severity ranking	Risk reducing measures	Comments
SFI 501.10.01	Safely lower and raise the FRC	Lower, rise, standby, test.	Moves uncontrolled	Broken wire, signal fail in remote/ control station, load limit exceded, brake fail	Inspection or in operation	Physical damage to FRC	System does not perform as expected, system might get further damaged.	Unknown	Catastrophic	Inspection, maintenance, procedures for launching the FRC	If the davit fails may crew get injured and evacuation /SAR/ transportation/ collection/ inspection inhibited.
			Does not move	Oxydation, brake fail, ice, power break	Inspection or in operation	FRC can not perform as intended	Entire system not functioning.	Unknown	Catastrophic	Inspection, maintenance, extra power supply, heating	

Figure 19- Failure Mode, Effect and Criticality Analysis flowchart (Løvmo, 2016)

Above is a picture of the completed general FMECA analysis form. One can make changes in the layout to fit the equipment or technical system better.

The Failure Mode, Effect and Criticality Analysis is a technique used to identify, prioritize and eliminate potential failures in a system, design or process. It is often used as a precautionary analysis to identify weak systems or equipment in the design phase in order to improve them before they are taken into use.

The criticality part of the FMECA is based on the consequence level and the history of such event. It shows that if the failure of a specific component will lead to great consequences and the component has a record of failing often is it a good indication that this part should be replaced by another option that scores lower on one or both points.

12.1.4.1 Definition and delimination of the system

The system is an FRC davit as demonstrated in 12.1.1.

12.1.4.2 Definition of the main functions of the system

The system shall store, launch and retrieve the FRC. Each task shall be performed at different times and only when the crew initiates the given task.

12.1.4.3 Description of the operational modes of the system

Standby: the davit holds the FRC steady in the crib while it is not in use.

Operation mode 1: Moving lengthwise and sideways to position FRC outside vessel. Lower FRC safely when operation initiated.

Operation mode 2: Lifting FRC safely from sea surface and maneuver back into standby position.

12.1.4.4 System breakdown into subsystems that can be handled effectively

The FRC is the subsystem of the davit. If the davit fails may it cause severe damage to the FRC. Protective layers might get scratched, which is a minor damage, or the FRC might hit the sea surface with such force that it breaks.

The crew is not looked upon as a subsystem, but rather as the users of the system.

12.1.4.5 Review of system functional diagrams and drawings to determine interrelationships between the various subsystems.

No drawings or diagrams exists at this point.

The system is quite small and isolated, and contains only the parts mentioned in 12.1.1 plus a number of pipes, hoses and joints.

12.1.4.6 Preparation of a complete component list for each subsystem

In this case will the FRC be looked upon as one subsystem, even if it is an assembly of several parts. This is because the physical trauma or limited function to one of these general parts will make an impact on the total subsystem when it is initiated from a davit failure.

12.1.4.7 Description of the operational and environmental stresses that may affect the system and its operation

In operation will wave hitting to the hull possible be great enough to, over time, make the materials tired. The FRC can move in high speed and the force on the hull will be greater by each knot. This might lead to and easier fraction force if the FRC should fall freely at a davit failure.

The davit will repeat the same movements every time it is operated. Joints will wear and demands regular maintenance.

Cold temperatures will make materials crispier and allow them to break easier. Hydraulics will also run slower and may therefore create a slowness or malfunction in the system. Icing might be able to lock parts that in operation is supposed to move, or in worst case intrude into pipes or cracks and break them.

12.1.5 FTA

12.1.5.1 Introduction

The most common method for risk and reliability studies today is the Fault Tree Analysis. The analysis will result in a diagram that displays the relationship between a potential critical event and its cause.

The analysis is often used to reveal all possible triggers that may harm the system and the probability for this to happen.

12.1.5.2 Define the issue and the boundary conditions of the system you wish to analyze.

The issue in this analysis is the davit lowering the FRC uncontrolled. Uncontrolled means that it lowers too fast, in fits and starts, free falling, or at the wrong time. The analysis shall identify what can cause such behavior.

For some equipment and technical systems will there be tens of different causes for a failure. It will be too time consuming and heavy to present them all here as the focus is on the method itself. Those conducting a full analysis in the future shall make their own decision on how many, if not all possible, causes shall be included, but for this demonstration will three events with three main causes that again has three triggering factor each be the limit.

12.1.5.3 Construct a fault tree.

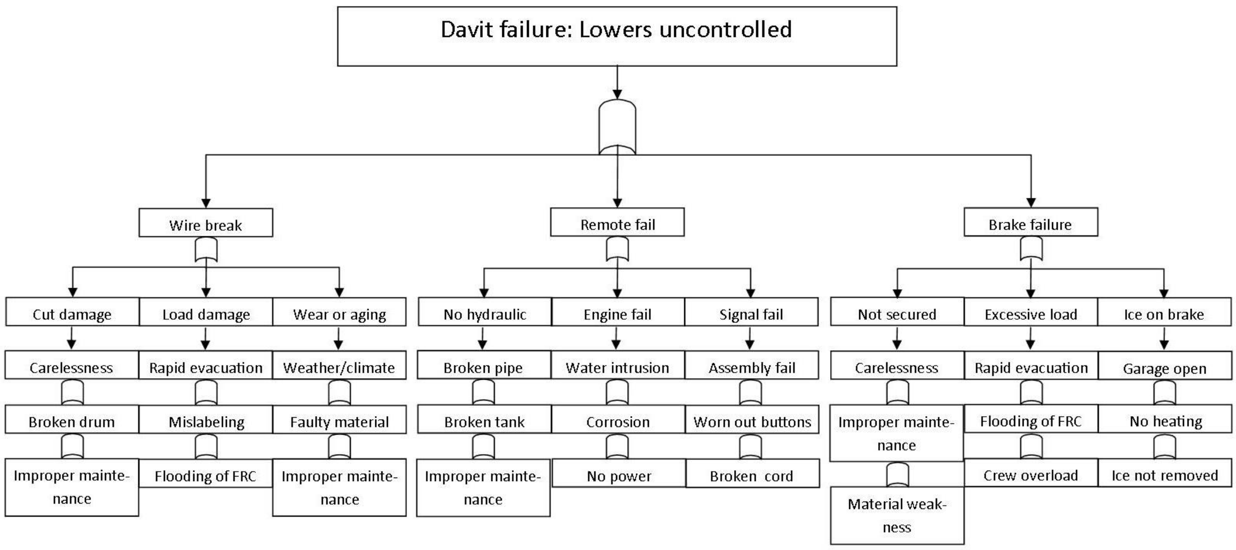

Figure 20- Fault Tree Analysis flowchart (Løvmo, 2016)

12.1.5.4 Identify minimal cut and/or path sets.

This FTA is quite simple and the minimal cut set is a constant of three. For the davit to fail must one of the three events occurs and they each needs only one main cause to do so. Each of the main causes needs just one of the listed triggering factors to occur, even though the frequency might increase if several appears at the same time.

12.1.5.5 Perform a qualitative analyze of the fault tree.

One can conclude that human error and improper maintenance is root causes that in many ways can result in a hazardous situations. In the example shown above will improper maintenance be possible triggering factors for all three events, which again often is a result of human error. The same can be said for several of the other triggers. A proactive and well designed maintenance plan will be one step on the road to secure the reliability of the system.

Outer factors such as temperature, humidity, strokes and weather will have an impact on the failure probability and must be evaluated when materials and design is chosen.

12.1.5.6 Perform a quantitative analyze of the fault tree.

No data available and calculations is therefore not performed.

12.1.6 ETA

The Event Tree Analysis starts at the initiating event, and then demonstrate the possible outcomes. One of the benefits with this analysis is that it includes the barriers that may stop or mitigate the chain of events. The ETA is commonly used in the design phase to visualize the effect of different barriers and showing the different chain of event that forms when the barrier is function or not.

12.1.6.1 Identification of a relevant initiating (accidental) event that may give rise to unwanted consequences

In one way may the actual need of the davit to lower the FRC be an initiating event. If the need is not present, the davit will not be able to fail in any other way than letting the FRC move in the garage in heavy seas. We read earlier that the initiating event should be "The first significant deviation from the normal situation that may lead to a system failure or an accident.", so the need of the FRC cannot alone contribute to the hazardous situation of a davit failure. The use of the FRC can also be seen as normal operation as it will be tested regularly and used for non-emergency operations from time to time as well. The sudden davit failure, on the other hand, will create a better initiating event as the elevated hazard for the crew will start at that point. Normal operation is as safe as one can tolerate if all procedures and conditions are considered and treated.

12.1.6.2 Identification of the safety functions that are designed to deal with the initiating event

To ensure that there are no persons below the FRC that will be injured if it should fall down should the boatswain at least visually inspect the below area before moving the FRC outside the vessel.

To protect themselves in normal operation as well as emergency shall the crew in the FRC wear an immersion suit or other clothing that will keep them dry and warm. This clothing will keep them from hypothermia both when the sea is splashing around the craft and if they should end up in the sea.

12.1.6.3 Construction of the event tree

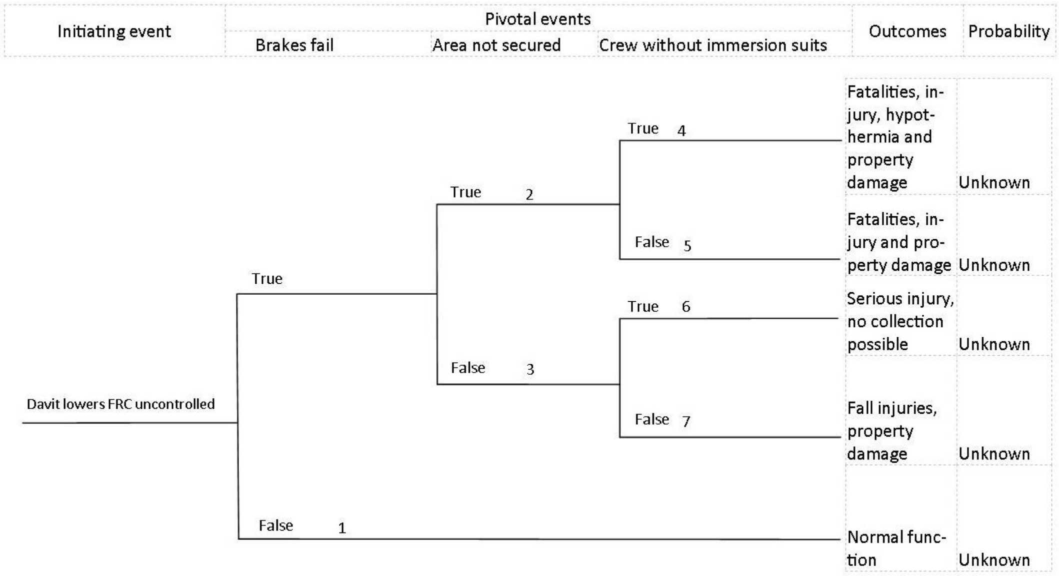

Figure 21- Event Tree Analysis flowchart (Løvmo, 2016)

12.1.6.4 Description of the resulting accident event sequence

On the figure above is all the possible paths numbered and they will now be described.

In all seven situations will the risk of falling from the FRC be present. This might be caused by slippery footing, negligence or misstep, as well as a reaction to movement or fear.

1. The davit will lower the FRC uncontrolled, but the brakes work, the area is secured and the crew wears appropriate PPE. This means that all the barriers function and they will stop and mitigate the situation.
2. The davit will start lowering the FRC uncontrolled and the bakes has failed so that these cannot stop the downwards motion. The area below is not secured so the falling FRC will be of danger to both the crew on board the FRC and those potentially beneath it.
3. The davit will start lowering the FRC uncontrolled and the bakes has failed so that these cannot stop the downwards motion. The area below is secured so the situation will only be dangerous for those on board the FRC.
4. The davit will start lowering the FRC uncontrolled and the bakes has failed so that these cannot stop the downwards motion. The area below is not secured so the falling FRC will be of danger to both the crew on board the FRC and those potentially beneath it. The crew is not wearing correct PPE and the risk of hypothermia will increase.

5. The davit will start lowering the FRC uncontrolled and the bakes has failed so that these cannot stop the downwards motion. The area below is not secured so the falling FRC will be of danger to both the crew on board the FRC and those potentially beneath it. The crew is wearing correct PPE and the risk of hypothermia is drastically decreased.
6. The davit will start lowering the FRC uncontrolled and the bakes has failed so that these cannot stop the downwards motion. The area below is secured so the situation will only be dangerous for those on board the FRC. The crew is not wearing correct PPE and the risk of hypothermia will increase.
7. The davit will start lowering the FRC uncontrolled and the bakes has failed so that these cannot stop the downwards motion. The area below is secured so the situation will only be dangerous for those on board the FRC. The crew is wearing correct PPE and the risk of hypothermia is drastically decreased.

12.1.6.5 Calculation of probabilities/frequencies for the identified consequences

There are no available data on this and calculation is therefore not possible.

12.1.6.6 Compilation and presentation of the results from the analysis

From the tree above is it visible that the criticality is exponential. As soon as the brakes fail will injuries be a possible outcome and the more barriers that fail the more severe may those injuries be.

The fall injuries will depend a lot of how the fall turns out. The human body is not symmetrical on all axes and therefore will some ways to hit the sea surface have a greater potential of creating trauma than others.

The immersion suit does not guarantee that the person wearing it survives, but it will increase the probability by approximately three times. It is estimated that a person will survive in the North Sea for about 30 minutes without proper suiting, and around one and a half hour with this suit on. Of course, this is very dependent on the person, the weather, the temperature and other circumstances, but it gives some understanding of which role the suit may have. Because of this are we not able to conclude on any certain difference between scenario 4 and 5, just assume that the probability for greater hazards exists in scenario 4.

All in all is there several "if-s" that can influence the consequence of each path, but there is also possible to see clear differences in the possible outcomes when the barrier is functioning or not.

12.1.7 The B. Apperry method

One method that did show up when searching the internet for already used methods designed with The Code in mind was this designed by Bertrand Appery.

Appery is a member of the International Institute of Marine Surveying with General and container cargoes, and State or government surveys as his fields of expertise. He wrote his article describing the method in 2007 as a result of his experiences as a master mariner and discussing the IMS 10.3 with his colleagues. He had then been at sea for most his life, of which more than 20 years as master mariner.

Firstly, Appery define that these groups of apparatus or systems are required to perform when the vessel is in operation:

- Propulsion, navigation and their management
- Port operations; manoeuver and commercial operations
- Power and its management
- Permanent safety; detection, lighting and eventually automatic fire extinction
- Response elements; extinction, fire or drainage pumps
- Survival; abandon, search and rescue

Appery chose to define the level of criticality based on which measures that is initiated to ensure the safe operation of the equipment or technical system.

- Critical without redundancy nor procedures of replacement
- Critical with procedure of replacement
- Critical with redundancy
- Critical with redundancy and procedure of replacement
- Not critical

12.1.7.1 Description of equipment or technical system

Description of davit is found in 12.1.1.

12.1.7.2 Level of criticality

The davit may fail to function at all, which will inhibit the use of the FRC. This may again inhibit evacuation, collection of objects and SAR, which all primarily is performed in order to save lives.

This davit might also fail in performing its tasks correctly. One example is that it moves the FRC in the garage or outside the ships side to rapidly or too slow. If it moves to slow will the planned operation take longer time, which might aggravate the situation if the operation is evacuation or SAR. If it moves too rapidly might the crew or items on board the FRC loose balance and fall, either into the FRC or over board into the water. This is also critical as injuries of different levels has great potential of occurring.

Based on this will the davit be in the category “Critical with redundancy and procedure of replacement”.

12.1.7.3 Specific measures

- Redundancy: having two or more davits and FRCs will provide an alternative if the first fails.
- Reinforced maintenance or more frequent tests by ship’s crew: will increase lifespan and reliability of the davit.
- Periodical control by specialized company: they should be able to spot weaknesses and early wear that the crew on board is not trained to do.
- Spare parts: limited space for spare parts on board will decrease the number of spare parts to a minimum. Small components that can be used all over the vessel such as hoses, couplings, nuts etc. is a minimum. There will not be possible to have a complete davit in spare parts stored on board.
- Familiarization and preparation of the ship’s crew: all on board should have enough knowledge on the system to be able to step in and assist if some or all of the designated operators is enabled.
- Special training for operators: those operating the FRC shall be specially trained in using the davit as well. They will be able to see the use of such technical system in a practical matter and might therefore be able to react early if something goes wrong.

12.1.7.4 Replacement procedures

- Hand drive operation on the spot (installed).
- Emergency power or fuel supply.

12.1.7.5 Risk analysis and operation in degraded status

The level of criticality is high as it may lead to any level of injury or even fatalities. The fact that the davit is part of a barrier itself will increase the criticality, and in this case is it easy to spot such connection. It might be harder in more complex systems, therefore is good knowledge of the analyzed system required.

One can see that measures that can increase the reliability exists. Some, such as maintenance, training and monitoring is relatively easy to implement. Others, such as keeping spare parts on board is possible to a certain level. Big and expensive elements will often not be ordered until they are needed, both since they will take up unnecessary space on board and because few will use money on an item they don't need in the foreseen future, especially if they can take other measures to prevent the situation.

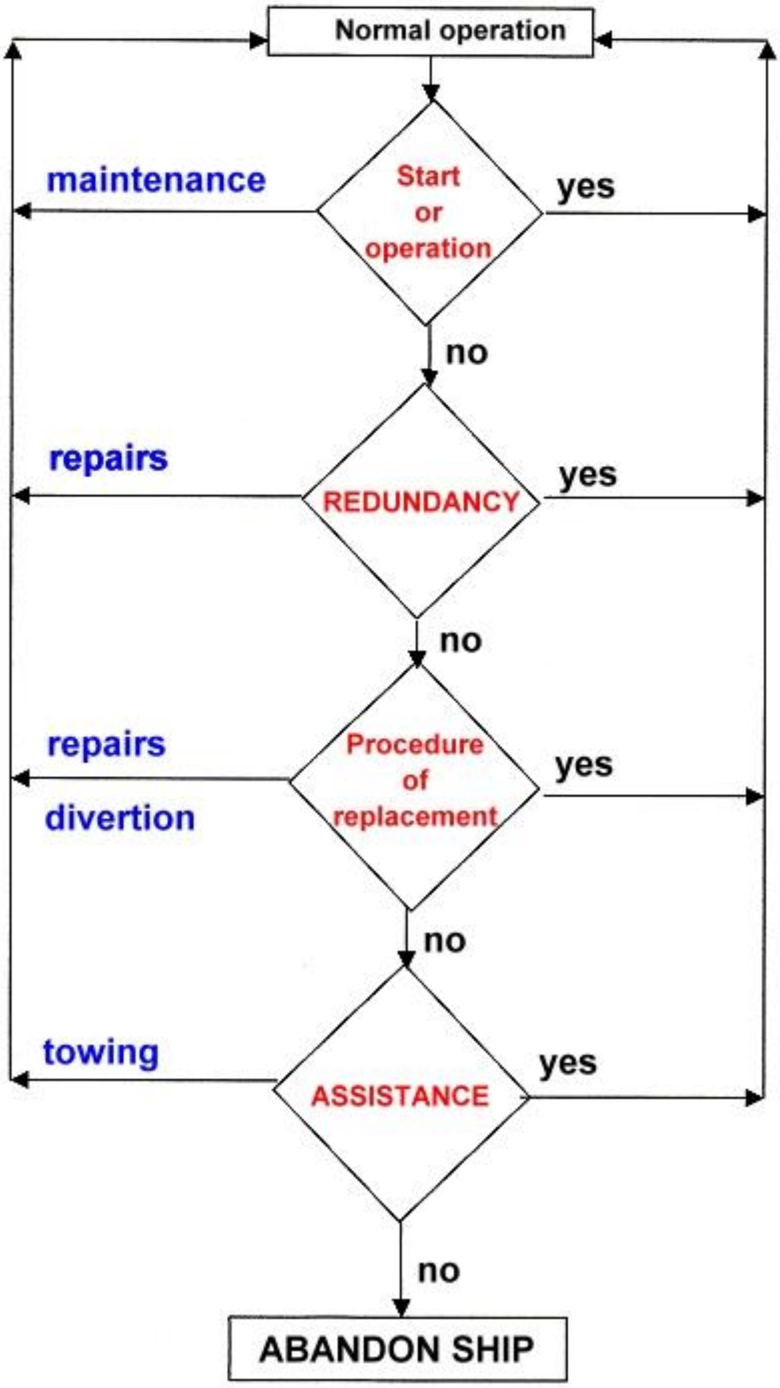

Figure 22- Apperry's operation flowchart (Afcan, 2007)

12.1.8 The Ajabu method

Another already existing method of analysis is the Ajabu method. Tasnifu Ajabu and his brother Ndugu both works at the University of Cape Town where they are contributing to The African Urban Risk Analysis Network. In 2011 were they contacted by a group of shipping companies that found it difficult to interpret the ISM 10.3 and to know if they were in compliance with it or not. The shipping companies and the Ajabu brothers cooperated close for nearly a year to develop a method that satisfied both the ISM and the mariner's needs.

12.1.8.1 A brief introduction of the equipment or technical system.

The davit is introduced in 12.1.1.

12.1.8.2 Scenarios.

The davit fails in two way:

a) it lowers the FRC uncontrollably
b) it does not lower the FRC at all

In both cases is it given that the davit is at a position where the FRC hangs outside the railing at the same height as the deck in the garage. If the FRC is in its initial position will scenario a) be inhibited by the davit and scenario b) be the intended event.

12.1.8.3 Consequences.

12.1.8.3.1 Situation a

If the FRC lowers uncontrollably, will the worst case scenario be that it with all its crew falls onto a quay full of people. The result may be serious injuries or fatalities.

An uncontrolled lowering of the FRC can be with or without persons inside the FRC. If there are no persons on board may the hazards include damage on FRC, damage to Arcturus, loss of FRC, parts/wire in the propellers of Arcturus, damage to objects located below the FRC and the hazard of not having an FRC available. If there are persons on board may there, in addition to the previously stated hazard, also be a threat to their physical and mental health and their life. The people in close vicinity that observe this situation may also get injured, either by flying parts or mentally by the experience.

12.1.8.3.2 Situation b

Scenario b) have two worst case scenarios: the crew cannot use the FRC for evacuation and the crew can not use the FRC to collect an object from the sea. The position of the FRC is not of any significance unless it is between the garage deck and the sea surface.

A fail in the lowering procedure may be discovered by inspections, at drills or in an emergency. If the FRC cannot be lowered may there occur an increased life-threatening situation for a person in the water, for crew trying to evacuate the Arcturus, or persons in fleets waiting to be towed or collected.

If the davit is unable to move along the rails so that it get is the release position may the main hazard be that the FRC will have the possibility to act as a pendulum if the Arcturus is rolling in the sea when launched. As shown on Figure 3- MV Troms Arcturus (Troms Offshore, 2014)does the ships side curve towards the centerline below the initial position of the FRC, while the ships side is straight at the launching position.

12.1.8.4 Criteria.

12.1.8.4.1 Situation a

To be in a position where the worst case scenario may happen a series of conditions must be fulfilled:

1. the vessel is alongside at port
2. the FRC is partially launched
3. the crew has entered the FRC
4. people are standing beneath the FRC
5. the davit fails

If one or more of these is removed, will the hazard be drastically reduced or eliminated.

12.1.8.4.2 Situation b

To be in a position where the worst case scenario may happen a series of conditions must be fulfilled:

1. There must be a situation that requires an evacuation
2. There must be crew that needs evacuation
3. Cross on dry land evacuation is not possible
4. There must be a person unintentionally in the water
5. Conditions inhibits use of ladder or dacon scoop to get person out of the water

12.1.8.5 Evaluation of initial consequence picture.

12.1.8.5.1 Situation a

The situation has potential of resulting in serious injuries or fatalities.

12.1.8.5.2 Situation b

The situation has potential of resulting in serious injuries or fatalities

12.1.8.6 Barriers.

12.1.8.6.1 Situation a

1. Being in port will eventually happen and is a part of the duties of Arcturus. Therefore can it not be any barrier to stop this event.
2. Launching the FRC is necessary to obtain duties, to drill and for inspections. Therefor must this action be initiated from time to time, but not necessarily while at port. This situation can be eliminated in certain circumstances.
3. The deck is too high above the sea surface for it to be safe for the crew to enter the FRC from there at all times. It might be a possibility to use a ladder if the sea and weather is on the good side, and one has time to do it that way.
4. People standing beneath may easily be eliminated by closing of a certain area on the quay. This is a simple measure that will eliminate the hazard for injuries or death on non-crew.
5. It will be impossible to eliminate a davit fail entirely, but the probability may be reduced by correct use of the equipment, correct and thoroughly planned maintenance, condition monitoring, regular testing and environmentally adaptive measures.

12.1.8.6.2 Situation b

1. Such situations may be fire, water intrusion, loss of stability, grounding or serious illness. All which have a low likeliness due to procedures and testing, but none of them can defined as completely improbable.
2. As long as the vessel is in a normal working situation will there always be crew on board. The number will change if she is carrying clients, passengers or her normal number of crew, or if she is at port and visitors also can be present.
3. If the vessel is at port will it be possible for the crew to walk from the vessel to a safe location. When at sea will dry land evacuation be possible if the weather- and sea conditions allow a safe transfer from Arcturus to another vessel on the sea by use of a ladder or by evacuation into a fleet without getting in the water in advance.
   It is not practical possible to keep the vessel in port at all times, as she would not fulfill her purpose as a vessel. The weather is neither possible to control at any time.
4. By “unintentionally” is people, such as surface swimmers and divers, who are in the water to perform a job excluded. To avoid falling into the water should prevailing safety measures be initiated. Safety harnesses and rope should be used when working in areas that may allow a fall into the water. In winter shall precaution be shown to

icing on the vessel and gangway, as well as if spills on deck occurs.
The risk of human error and “bad luck” will be major in this event. Therefore will it be impossible to totally eliminate it, but correct behavior and understanding of the job and circumstance will help lowering the risk majorly.

5. The use of a ladder or dacon scoop will eliminate the risk of the crew that maneuvers the FRC at all times, but there is not always possible to use those solutions. The person in the water has to be conscious and able to think and move in the water. If he is not wearing an immersion suit, he might be too cold to have the necessary motoric function and consciousness to move himself close to the vessel and/or climb the ladder. The weather and/or the sea might also be too rough for a person to move controlled in the water. The person must not hit into the vessel and, more important, not get ran over. This might be hard to avoid when the sea is rough and the vessel should in this case move slowly away from the person. There will be possible to send a skilled swimmer into the water connected to the vessel with a rope or a wire. He may then swim to the person and keep a tight grip on him as the rest of the crew pulls them both towards the dacon scoop and lift them into the vessel. Again, the weather is uncontrollable and even if the vessel position herself in a way that provides shelter for the person is there no guarantee that the person is in a condition that allows him to use the ladder or dacon scoop.

Figure 23- Dacon scoop (Marinelink, 2014)

12.1.8.7 Evaluation of overall consequence picture.

Some of the criteria that must be fulfilled for the worst case scenario to be possible can be eliminated, but not all. The consequences is also shown to fit as critical according to the definition. Therefore is it not correct to say that the hazard the use of this equipment can be eliminated by procedures, training and maintenance.

12.1.8.1 Measures that can be taken to reduce hazard

A maintenance plan suited for the specific vessel/ vessel type and her crew is to recommend. In this way will there be a uniform understanding among the crew how the procedures shall be completed and what aids are available to execute such operations.

If there are any special equipment (such as an FRC and not a MOB-vessel) will there be essential to train the crew on given vessel in operating and understanding this equipment instead of providing a brief overview to all crew in the fleet. In an emergency will each crewmember hold a designated role on board and is expected to be able to perform in both perfect and horrible conditions. If a person has a complete understanding of how the davit and the FRC works will he be able to understand possible underlying causes of a fault and therefore be able to identify the risk of them happening before they actually occurs. He will also have a better opportunity to solve any problems that may occur when the FRC is on the sea.

On Figure 24- Troms Pollux with garage closed and Figure 25- Troms Pollux with garage open, we see clear pictures of the FRC and davit garage on Troms Pollux. Arcturus has the same garage with a protection wall, which protects both the davit, the FRC and crew against weather and sea. Salt water sprayed on the equipment may lead to corrosion on the equipment and the fabric drying out on the FRC. The plastic screen may also lose its transparency. These hazards will decrease the lifespan of the equipment and demand a greater frequency of maintenance, which both are expensive and time consuming.

The wall has a rupture strength that is lower than the force the davit can launch the FRC. In other words is it possible to break the wall by force if it should not open as supposed.

Since there shall be possible to transfer people to and from the FRC while it is alongside hoisted up is there no railing on this part of the deck. If there is heavy weather and the vessel is rolling may there be a great hazard of crew falling down in the sea if the wall is not present. The crew shall evaluate the prevailing circumstances and decide if harnesses and safety ropes shall be included as a part of the protection equipment for crew working in the area.

12.1.8.2 Additional information.

Physical and mental damage shall be considered the most hazardous consequence of a davit fault. There is no guarantee that those damages can be healed, and there is no way of determine the time it will take to heal if such is even possible.

After the hazard to humans should the environment be considered. The most environmentally hazardous situation will be if the FRC and/or davit falls into the sea. Both is made of materials that is not easily degradable and may cause harm for a long time. The davit has so high density that it will sink almost immediately and may be found and collected later if the depth make this possible. If is stays on the sea bottom it may be a problem for dredgers, fishing vessels and vessels anchoring in the area.

Hydraulic oil may leak out into the sea and be of danger to fish, birds, other animals living in the sea and secondary feeders such as humans. Parts of the FRC is made of a material that has such density that it may float below the sea surface for a long time. It may be eaten by larger animals, get stuck on animals or degrade into smaller pieces and be swallowed so that it cause harm to the smaller animals' digestive system.

The economical consequences may in some cases also be evaluated. The equipment itself is expensive and will lead to an unnecessary cost to replace. If another vessel is harmed, either directly by the FRC falling onto it or indirectly by the vessel getting parts into the propellers, there might be an insurance matter that may lead to a considerable cost to the shipping company. This will lead to loss of income and a poor reputation of the vessel and shipping company.

Economy and criticality should only be in the same sentence when the level of criticality determine how much one shall budget to ensure the reliability, never in order to estimate the criticality in a way that justifies the budget.

Figure 24- Troms Pollux with garage closed (Skipsfarts-forum, 2013)

Figure 25- Troms Pollux with garage open (trawlerphotos, 2011)

13 Authors evaluation of methods

13.1 General

Since there was no time to perform all analyses on more equipment or technical systems will the analysis of the davit be compared to how a similar analysis of an Electronic Chart Display and Information System (ECDIS) may have resulted when possible.

An Electronic Chart Display and Information System is a computer based aid to navigation that can eliminate the necessity for chart. A map containing all necessary info is shown on a monitor and the navigators have the opportunity to add different tools that can help them plan and monitor the voyage. The author has basic experience of this system from nautical studies and will use a general version of this when discussing the analysis.

None of the methods is perfect. One might cover one aspect very good, but fail on the next so that the method alone is useless for the purpose of identifying the critical equipment or technical system.

Presenting diagrams and drawings when analyzing the system would always be a useful tool in order to get all on board. Such information is not always available, or might be a composition of several different sheets. If the diagram is clean and one can anticipate that all intended readers will understand it will such be a positive additive, but if the other situation is the case might adding this lead to less understanding. Some systems may have extremely complex diagrams that can take the courage from anyone and some might not have space enough available to be constructed in a logical way. Some people may also believe that they understand it, but in reality do they mix up two very different components and in that way end up with a wrong interpretation of the entire analysis.

Ensuring a logical and well-designed diagram is therefore necessary before including it in the analysis. If this is achieved might the diagram be the detail that solves the puzzle and provides complete understanding of what might be an partially unknown system that shall be operated.

None of the methods was presented with highlighted weaknesses. This was done deliberately to see if the expert panels discovered those weaknesses.

13.2 FMECA

13.2.1 Credibility

The FMECA flowchart used in 11.6.2 is based on a very simple template, but does actually provide good and simple information. Even if some of the headlines might be unknown phrases and words will the text in the below cell have the opportunity to put it all into context.

This is a simple system, but the FMECA flowchart will be able to carry a lot of information and may be adjusted to suit the purpose even better.

13.2.2 Transferability

Defining the subsystem is relatively simple in this example, but a modern vessel have several more complex equipment and technical systems that would need careful consideration. One of the goals when performing this analysis is to uncover situations when a sudden failure of one system is safe, but will make another system fail and initiate a hazardous situation. The FMECA facilitates this is a good way as it breaks the system into subsystems and evaluate them separately, if one knows all the subsystems that is.

Adding functional diagrams and drawings will visualize the system and make it easier to understand where the connections are found. Not all systems have such diagrams, especially systems that is not entirely electric or hydraulic/pneumatic controlled. If the system is very simple and self explanatory is it unnecessary to consider it further, but other systems could have a major uplift if such diagram is constructed. If one knows how the system works is it easier to treat and maintain it correctly as well.

A very suitable aspect from the FMECA is that is also includes operational and environmental stress. For vessels operating in the high north is this important to mention as temperatures and rough weather may impair equipment and technical systems that are exposed. When completing a quantitative analysis will this become visible, as the failure rate will increase for a non-specialized equipment or technical system.

To sum up is this method transferable in some way. If an ECDIS had been analyzed would it have a lot of components and subsystems that needs identification and treatment, and it is not certain that the result presented in that flowchart would be highly understandable. The definition of subsystem is not entirely clear, but it is reasonably to think that it means systems that receives information from the ECDIS. The list of systems sending information to the ECDIS will be greater, but we cannot see a good way to express that these systems cannot perform their task as intended unless they are cause of the sudden failure.

13.2.3 Dependability

The dependability is hard to confirm, but not necessary due to the analysis itself. It you allow two persons that know and fully understand the given equipment or technical system will assuming the same result be legit. The analysis itself can be processed based on facts only and as long as there is no “if so then might” thoughts that needs to be evaluated will it be relatively straight forward.

If those performing the analysis has different understanding of the equipment and technical system may the result be different. They may define the failure mode differently, which will bring differences through the rest of the analysis. The effect of failure can also be defined differently and create diversity from that stage.

The severity ranking levels should be defined in advance on a more general ground, but the judgement of different people might provide different ranking. All in all, the composition of the team performing the analysis must be taken very serious in order to secure the dependability of this method.

13.2.4 Confirmability

The method have room for endless information in the text, but it should be kept to a minimum in the flowchart. Choosing what to state in both of those might be hard if the equipment or technical system is complex and need therefore extra consideration in such cases. Keep the text informative and simple as well as including all that is necessary, that is the most important.

13.2.5 Additional remarks

The overall goal is to determine if the equipment or technical system is critical, but this FMECA does not spell the sentence “yes, this is critical” in any way. One may define that “if the equipment or technical system have a failure mode then it is critical” or similar, but this might lead to all equipment and technical systems being critical. The same might happen if one chose to try this with the “Effect of failure” instead. Generalizing and stating that all effect is critical will show a low ability to evaluate the situation. The best might be defining the levels in severity ranking so that any equipment or technical system that scores above/below (depending on how it is defined) a certain rank is critical. The definitions of every rank has to be considered carefully and described in details so that other persons than those who define it first can use the analysis and get the same results. Be careful and define the ranks in a way that always will courage a higher criticality when in doubt.

How the failure is detected will not need this much attention as it will be practically difficult to detect a sudden failure. If indications of a progressing failure that have the potential to create a hazardous situation is observed shall it immediately be taken measures to stop the chain of event and the failure will not be sudden. The davit will never be used if it is known that there is something wrong with it, at least for as long as the alternative of not using it is less hazardous.

13.3 FTA

13.3.1 Credibility

The fault tree itself is, if designed good, understandable for a majority of the population. Space might be an issue as one wish to keep it organized and simple, but also make it contain enough information to state the point.

To ensure that all keep track should a symbol explanation be visible along with the tree. For complex systems might different colors on the cells be an idea to separate them or the path easily.

An idea for improvement is to label all cells with numbers so that they can be explained later on in a list or similar, like the ETA is.

13.3.2 Transferability

Since the tree is possible to complete in an infinite number of ways will this method, in theory, be usable on all equipment and technical systems. Even if the possibility is there, can it not be said that it will be a good idea to do so. Just think about this simple davit that created the tree we have seen, and then imagine a more intricate system. It will almost definitely be chaotic and hard to understand.

It could be used on small components and then be put together in a greater system, but the time consumed doing this would probably not be worth the result.

13.3.3 Dependability

Just as for the FMECA will the result of the analysis depend on the knowledge of the analysists. If all understand the equipment or technical system fully is there a good chance that the results will be the same. The uncertainty will be higher here than for the FMECA as more complex systems can get out of control and defining what the events or triggers are can be different from person to person.

13.3.4 Confirmability

If one strive to make the flowsheet easy and good looking will the cells for text have limited room for information. The analysis text have room for a lot of information and boundaries will be necessary in order to not get too much.

13.3.5 Additional remarks

An advantage with the FTA is that it enlighten what the issue really is and what boundary condition this issue have. As mentioned will there be several complex systems found on a modern vessel and clarifying what one includes in the system and what has been excluded will be wise. Defining the issue will be the same as describing the failure mode in FMECA or the Ajabu method.

It is positive that the method has both a quantitative and a qualitative side. Some systems do not have enough data or is too complex to perform a quantitative analysis and then would it be more favorable to conduct a qualitative analysis than guessing values, even if one can provide qualified guesses.

A major downside with the FTA is that it does not describe the consequences or events that the top event may cause. This is what we are looking for to be able to determine whether the sudden failure of the equipment or technical system may result in a hazardous situation.

The FTA does not include barriers either, which is essential to ensure the reliability of the equipment or technical system.

It is not easy visualizing how this method would look like for the ECDIS, but guessing that it would become rather large and intricate cannot be too far from the truth.

In a planning state before the equipment or technical system is installed can this method be useful. One can imagine an event that could be hazardous and from then brainstorm the reasons for this event. Out of this may places to install barriers be evaluated and the system constructed safer before installation takes place.

13.4 ETA

13.4.1 Credibility

For this example could the method be easy to understand, but the tree could get very complex for a larger system. Even for this example was several barriers not marked in order to provide a flowchart that could be viewed off all participants.

13.4.2 Transferability

The method would probably work on all equipment or technical systems, but it might be harder to define the paths in certain situations.

Again, the transferability is only as strong as the analysists knowledge.

13.4.3 Dependability

If the analysists know the equipment or technical system is there a good chance that this method will provide the same results several times. If you know all the barriers and know how they works will the construction and description follow the template towards the final outcomes.

13.4.4 Confirmability

The description can contain as much information as one needs. The flowchart will have limited space for information, but as shown in the example can the paths be numbered and described one at the time.

13.4.5 Additional remarks

Unlike the FTA will the ETA not explain why the event occurs, only the sequence afterwards. There will therefore not be possible to determine if the situation is plausible to take place or not and which barrier might be installed in order to inhibit the event in addition to those installed to mitigate the consequence. The consequence is on the other hand well described.

Just as the FTA will this method be more helpful in a planning state, especially if the equipment or technical system is already decided. One can think that a rebuilding of a vessel will be the perfect place to use the ETA as one can improve already installed equipment or technical systems to improve their reliability or to meet new regulations.

The great advantage of the ETA is that it considers the barriers that is installed. When working with the equipment or technical system every day is it crucial to know what your aids are if something should go wrong. These barriers must be noticed in order to maintain their function in order to ensure the system reliability.

Since Probability is not achievable in this case could possibly this column be altered to Criticality status. In that way would it be easy to glance at the flowchart to know if the equipment or technical system is critical or not.

Even if the method could process rather large equipment or technical systems would this be a very time consuming job. It does only care for one event at the time so when the equipment or technical system has several failure modes will the job escalate, which needs to be considered before such is performed on a vessel with several hundreds of components.

13.5 The B. Apperry method

13.5.1 Credibility

The method can be tricky to understand for all intended readers. Trainees or others that are new in the maritime industry might have a hard time understanding why the equipment or technical system is placed in a certain group if this is not described well enough.

13.5.2 Transferability

The method will work on all equipment and technical systems, as long as they fit into the groups of apparatus that is required to perform when the vessel is in operation. Well, if they don't fit into any of those groups will the equipment or technical system not be critical as it is not required to function, but this does not take the sudden failure into account. Even if the system is not needed may there be linked systems that is required. The sudden failure might also be a dangerous situation in itself as an explosion or creating a fire. This is something that should be included in the method.

13.5.3 Dependability

Once again, knowledge of the equipment or technical system is alpha and omega in order to get the same results. If the method is understood and the competence on the equipment or technical system exists is it reasonably to presume that different analysts can achieve the same result.

13.5.4 Confirmability

The confirmability will depend on how much the analysts choose to include in their analysis. If they only answer by the predefined sentences may there be uncertainty on how this result was found. There is nothing inhibiting them in explaining their choice and it would be a good idea to consider this from analysis to analysis as some might be so straight forward that further explanation is unnecessary.

13.5.5 Additional remarks

Since Mr. Appery is a master mariner was there great expectations to him providing a good method.

If you know the equipment or technical system and understand the method fully might this be a very quick method to use. The classes Appery defines can also be useful to just have in mind when discussing equipment or technical systems. Let us say one sits in a planning meeting discussing the alteration or exchange of a certain equipment or technical system. If one then estimates the criticality, imagine the measures that is needed to ensure reliability, think about how the replacement procedures can be set, analyze the risk in degraded status and at the end set all this up against the available space, economy and tolerances. This could be a quick thought-tool in order to choose between different equipment or technical systems, or even the use and placement of those.

In those cases where the equipment or technical system is rather complex might it become hard to keep track for the common reader without a flowchart that visualizes the process. Perhaps stating the facts in a straight forward table could help enough so that all the thoughts are sorted and presented in a way that is quickly understandable.

This method does in some way determine if the equipment or technical system is critical or not. In point two shall the criticality be determined, but there is no information on what it is critical to. Is it the vessel, the crew, the environment, the economic state or perhaps something different? This has to be made more clear and perhaps fitted to the given type of vessel and company as long as it has the minimum demands in the bottom.

The connection to other equipment and technical systems has no natural place in this method. This should be added in some way to ensure that all connections are made visible. In case of an ECDIS analysis would it probably be too little information to get the whole overview presented, unless the analysis of risk and operation in degraded state is done perfectly.

13.6 The Ajabu method

13.6.1 Credibility

The method follows defined steps that is found again in the flowchart. The intension is that those that just want to check if the equipment or technical system is critical may glance at the flowchart and notice whether it is marked red, yellow or green, and those who want to know more details can check the connected chapter in the analysis. The traffic light is intuitive and will, in connection with the brief explanation of where the limits are, be understandable for all.

13.6.2 Transferability

The flowchart is suitable for the thinkable equipment and technical systems on board a modern PSV. It has not been tested well enough so this need still confirmation. Since the flowchart is made in Excel may the cells be rescaled when necessary, but it might become confusing when the equipment or technical system is large and complex. The frames may be made thicker to separate the cells better.

13.6.3 Dependability

Unlike the three first methods does this method require a certain amount of brainstorming and boundary settings. It seeks the worst case scenario, which may take some thinking to discover in some cases. The thought was that if one looks at the worst case scenario will one be able to determine if the equipment or technical system is critical or not, and then, if critical, have a look at other possible outcomes. If the worst case scenario is not critical, then will the less worst scenario not be critical either. By doing it this way may the workload be less for those completing the full vessel analysis as they will not have to proceed with those equipment or technical systems that are not critical and can therefore focus more on the critical.

Just as the other methods is knowledge about the equipment and technical system needed. This will be crucial to complete a good brainstorming and end up with the real worst case scenario. If the person conducting the analysis is somewhat uncertain of his/hers knowledge on the system should a control analysis be conducted, especially if this person finds the equipment or technical system not critical. It will be safer if the person finds the equipment or technical system critical without possessing the expertise, but then again will it be loss of available time if the criteria never can be fulfilled.

13.6.4 Confirmability

This method has a lot room for information both in the flowchart and in the text. Due to the Excel format can the cells be sized how one wishes to suit the amount of text that is needed. The layout might be somewhat confusing if the amount of information gets too high.

13.6.5 Additional remarks

Due to the fact that the author of the thesis has designed this method is there possible that the analysis made in 13.6 is inaccurate and should be analyzed once more by someone else. The experts has evaluated this method and there will be presented more of their comments on this method just to be sure that it get a good walkthrough.

The comments section can be used in many ways, for example to define possible connections to other systems that may be interfered by a sudden failure. The influence on other systems is important and it would probably be beneficiary to have a dedicated column in the sheet.

The idea to the new method comes from the FMECA. The flowchart was viewed as easy to understand. The author wanted originally just to optimize the FMECA, but as the work went on did she see that the new flowsheet focused on something different from the FMECA so it had to be referred to as two methods.

14 Expert panel feedback

14.1 Introduction

The expert panels is expected to revert with both their personal thoughts, but also how they think the different methods will be interpreted by other people in the same position as themselves.

The author has not knowledge of the background of all participants, but few of them is expected to have a greater understanding of the different methods from previous education and experience. This is negative as they can only base their opinion on the examples presented by the author, but also positive as they will have to use all their experience from marine operations to make up their decision.

Other than answers to the direct questions, we hope to reveal if all agree on the same, if there are similarities among the different positions, as well as how people with highly practical jobs interpret schoolbook-methods.

14.2 Feedback from expert panels

First will remarks from the experts and visible resemblances the author finds among the answers be discussed and then will the different methods be closer evaluated with comments and remarks in the following sub chapters.

One of the participant showed a stronger feeling towards the content of the analysis rather than the testing of different methods. That is kind of logically as this is a technician, but it did not provide so much feedback on the methods.

Some of the participants did not notice that it was a presentation of five different methods, but rather as a large method containing five larger steps that would together be an analysis of the davit. Why the participants came to this interpretation is unknown and might contain several factors, but it is an interesting observation. It would be possible to create a new method consisting of different steps that take care of different aspects of the analyzed equipment or technical systems. One step is analyzing the barriers, the next analyze the risk, the one after analyze the human and so on. This is a general thought and may not suit the purpose of ISM 10.3 fully. This needs to be tested further in order to make any conclusions.

This has led to fewer answers than hoped. It was expected that some would decline to participate, which they was fully entitled to, but this misinterpretation lowered the number of useful feedback even more. Not that their answers is not usable, it is just that they have not looked at each method separately and there is no way one can understand what they mean when they refer to the method. It is likely the whole thing, but since the same aspect is presented multiple times is there multiple places their comment may be suitable.

The two first answers that came back came from two chief engineers. They both gave the exactly same answer on how such overview would affect their job: they saw the methods as a tool to be included in the maintenance plan for the vessel. First of all, it is great that the crew finds a purpose of a list with critical components. It is reasonable to believe that several crew members, both engineers and the others, will make this connection as maintenance is a major part of their every day job. The list and the plan has several connections, for example will maintenance be a barrier that may prevent a hazardous situation, but the list will also determine which equipment or technical system which the maintenance plan must be considered most.

The amount of information on the different method was looked upon differently. Almost half of them said that they was happy with the information that was presented and the rest felt they could need some more information. As expected was those feeling they had enough information those with high positions and a long career at sea, presumably because they are well familiar with the equipment and have experienced different versions of those.

14.2.1 Participants in expert panels

When asking for feedback from the experts was also their experience and permission to quote asked. They were also told to estimate how representative they felt among people with the same position. This, as well as if they think a list of critical equipment and technical systems will be useful for their everyday job will be shortly presented before presenting their feedback.

14.2.1.1 Danish chief engineer:

- Believes he is representative for 4 out of 6 chief engineers.
- "I don't think that an overview of critical equipment will have a huge influence on my job on this ship. But if I was assigned to a new building, such a list would be handy. In my opinion it is a tool more suited to new buildings, because on such it would be a method of assessing which systems are redundant and which are critical. This could help when building up the maintenance system of a new ship, and help for deciding which spare parts are necessary to keep on board in addition to those required by the classification society."

14.2.1.2 Norwegian deck cadet:

- "Other persons in the same rank as myself will be representative for the answers in this feedback. Although different amount of experience might affect the thoroughly understanding for critical components. Taking into account that STCW is situated in basis of our education, most people in the same rank as myself will be representative."
- "An overview of critical equipment would have a positive influence on my job. This would serve as a useful tool during training in the use of equipment. Even though I never have experienced other situations, my opinion is that an overview would be useful for any person, that by requirements must be a user of the equipment, but still lack the technical understanding of the sub systems."

14.2.1.3 Norwegian QHSE Manager:

- "My position is onshore QHSE Manager. I believe I would be fairly representative for persons in similar positions. My combination between technical, nautical and human factors education combined with seagoing time makes my background quite unique, and hence may affect my answers compared to my peers and in particular sailing personnel. Also I am known to be extremely analytic."
- "As my position is onshore, I don't think it would affect me personally too much. I don't necessarily believe that such an overview will make the vessels crew's tasks

easier, however I do believe that if performed properly it will enhance the vessel's safety."

14.2.1.4 Norwegian Senior QHSE Advisor:

- "Safety education, but no practical experience as a seafarer. Other persons in the same rank as me with background as seafarers might have a more practical approach to analyzing the different methods."
- "It would help when developing maintenance procedures and risk analysis for specific operations. By having an overview of critical equipment you will be able to easily identify which equipment that might need more stringent maintenance routines/intervals than other equipment. It would also be helpful when planning/risk assessing specific operations where critical equipment is used/needed."

14.2.1.5 Polish chief engineer:

- "I do think, my answers will be common for around 60% of engineers same rank with different background."
- "Overview of critical equipment mostly influence critical spares inventory control and purchasing of parts. It also helps review of planned maintenance system.
  In practical life on board, it helps pass classification and port state inspections. Ship crew usually will get ready procedures based on analysis and usually does not receive methodology, how procedures were developed."

14.2.1.6 Anonymous #3*:*

- "I think it might influence my job in several ways , but mainly in planning and budgeting of spare parts and in crises management. We have had several instances where this could have been needed, but mainly as response to auditors and class. I think when you operate vessels as close to a base or suppliers as we do and with vessels with multiple backup systems , this becomes less significant than it would with deep sea vesssels or with vessels operating in remote areas."

In addition to these do we also have Anonymous #1 and Anonymous #2, which did not allow their name, position, nationality or any identifiable details written.

14.2.2 FMECA

14.2.2.1 Danish chief engineer:

"I find this example easily understandable.

The template makes great sense to me, as I find it a logic way to work. A helpful thing is the SFI ref No in the beginning of the template. I also like the brief description of the intended function and the operational mode, as these descriptions give a common understanding on which functions of the equipment that are being analyzed."

"I believe that this system can be used on all systems on board. The use of the SFI code makes the definition on the system / sub system correspond with the defined limits of each system in accordance with good practice on board ships

This method will work equally well on very large and very simple systems, provided that a definition similar to the SFI system is made first on the large systems, so as to define what is part of the system and what is not."

"This method would give the same results on other types of vessels, if those vessels had traded in the same areas. E.g. a PSV based on the west coast of Africa would most likely not experience any difficulties with icing and cold temperatures. And like wise on ships with the FRC mounted at a comparatively low height above the water, the fall injuries that the crew could sustain would be lesser.

Previous experience from the following types of vessels: LPG tankers, Reefer vessels, Product tanker, High speed ferry, Construction vessel."

Previous experience stated on each method and will not be repeated in this presentation.

"The chosen method will reveal all the realistic imaginable effects based on the experience of the person who fills in the template. If someone without any knowledge of a similar system is to fill in a template, it is possible that the result might not be realistic or satisfactorily evaluated."

"The method describes "risk reducing measures", which I believe can be viewed as information about barriers. But since this method is intended to be used as a help for professionals ,there is no need for further information concerning the system, as the end users of the document i.e. the FMECA template are expected to be people who will already have knowledge about the system (professionals)."

"A description of the main particulars of the system would be handy, in this case the davit i.e. the same information which is given on the top of page 3: Aukra Maritime AMDT-3700, swl 3700 kg, nom speed 0-50 m/min, max list 20 dg, max trim 10 dg, temp range -20 - +40 dgC"

"The method will require a person with a relevant experience to fill in the template."

14.2.2.1 Norwegian Deck cadet:

"The way the method was presented was good. It was presented in a way that the usage of the method could easily be understood by viewing the illustrations and reading the descriptions. Although it would require that the users would have basic knowledge in the use of the equipment. For me, with the basic knowledge, I found the illustration of the method most useful. The sub chapters were a good way to supplement the understanding of the method."

The above quote was stated on all methods and will not be repeated.

"This method should fit any equipment and technical system. Although, if used on very complexed systems, a complete overview will also become complexed. A breakdown of the system into sub systems might be required before applying the method on each sub system, instead of the total system. This should fit small systems without being to detailed."

"By combining the illustration and the sub chapters, the user might get an understanding of the barriers. This should be more clarified, maybe by an own sub chapter."

"My overall impression of the method is that it gives a general understanding of the critical components of the equipment. Which might be good for first time users of the equipment, but bad for advanced users."

"By dividing the on row type into more rows, the method could become more specific. For example, "Description of failure" could be divided into more rows, to more specifically could define the effects on the sub systems."

14.2.2.1 Norwegian QHSE Manager:

"Good choice of system for example. Easy to understand.

I Miss illustrations, drawings and manuals in order to understand functionality of system.

Example does not give a "cook book" recipe for how to perform the analysis. For instance there is no description of severity ranking.

The method is very structured, but is tedious and may be very time consuming."

The above quote was stated on all methods and will not be repeated.

“This method does not address combination of failures. Such as for instance the FTA will.”

“I believe it “ticks all the boxes” of the ISM code, and is subsequently detailed enough.

Method has been proven to handle larger systems, but may be very time consuming.

I do not believe it is too detailed for simple systems (it will only be less time consuming).”

“The method is only as good as the people performing the analysis. “

“I think this is good enough. No need for further explanation. Again limitation is people performing the analysis.”

“The tabular approach gives a good overview.”

“For application on PSVs, Failure rate may be removed, as there is very little statistical data available for systems/ components. SUbsequently only a qualitative approach would be possible.”

“Would be my second choice of the 5 methods presented.”

14.2.2.2 Norwegian Senior QHSE Advisor:

“Using this method on more complex systems might be challenging due to several different failure modes and effects of failures. Failure rate might be difficult to quantify. Might get to detailed and comprehensive when trying to apply and understand the result of the analysis for persons without any specific education within use of the FMECA method.”

“The method itself a good tool to reveal such possible effects (effects on other equipment or technical systems, authors note), if used correctly. The layout of the flowchart, connecting effects of failure to each failure mode is very logical and easy to understand. So in theory I would feel very secure. However, as with all methods, “shit in equals shit out”. I.e., it would be extremely comprehensive and challenging to determine all possible failure effects that all equipment onboard might have on surrounding equipment and technical systems. In my opinion this would be too big a task for the ordinary user of this method within a shipping company.”

“The barrier part of the method is OK, I would say 3-4 on a scale from 1 to 6. Barriers are included in the “Risk reducing measures” part of the flowchart. They are visible, but not presented in detail. Each barrier is not clearly linked towards a failure cause or mechanism, which would make it easier to connect each barrier towards a specific cause and further on ensure that each potential cause has received a proper/applicable barrier.”

"My overall impression is that this method is a well arranged flowchart that gives a good overview of the system being analyzed. However, when used on more complex systems it might have to include too many factors/information, making it (the flowchart) challenging to use/understand."

14.2.2.3 Summary

It is visible that the FMECA was considered a good method among the participants. They agree that it is logic and displays the information as intended.

They seem to like the visualization made by the flowchart, which is interesting as they who answered every method have very different background and job title.

They also agree that it will work on all equipment and technical systems, but how understandable the results will be is not entirely clear. It is suggested to split the cells in order to cover more of the systems when they are more complex.

The Danish engineer appreciates the SFI code in the start of the flowchart. This is natural since he will be working with such numbers all the time and will probably fast be drawn towards the given type of equipment only by reading this number. The SFI (Skipsteknisk Forskningsinstitutt) codes is international codes that are common all over the world. This means that a mariner on one type of vessel in the southern hemisphere and another on a second type of vessel in the northern hemisphere will be able to identify the same type of equipment from looking at the number. The make and model will of course vary so those detail needs explanation in the given case.

There is raised a question whether the method will work on larger and more complex system, but the experts does not all agree as some thinks this will work out fine.

14.2.3 FTA

14.2.3.1 Danish chief engineer:

“The method is understandable, but it gives a messy impression. Furthermore there is no description of the eventual outcome of the failure in terms of damage to people or the FRC itself.”

“I feel that it would make more sense if the arrows were pointing in the opposite direction i.e. towards the “davit failure”. That would make more sense in reading the diagram.

E.g. “Broken hydraulic pipe” leads to “no hydraulic” leads to “remote fail” leads to “Davit failure”.”

“I do not believe this method will be usable on all equipment on board a vessel, because it fails to give a clear overview.

It could work on a very simple system, but even a davit is probably too complicated system for this method”

“This method would have had the same challenges on other types of vessels, and it would not have been a good method on those as well.”

“This method doesn’t seem to address the effect of the sudden failure on other systems. So I am not in any way sure that this method would reveal those.”

“I feel that the necessary means/barriers to degrade the hazardous situation are not mentioned in this method.”

“Overall I am not impressed with this method. It gives a cluttered impression and it seems to be of little use to me.”

“I think the method is unsuited to the task, and there are no easy changes or additions that will be able to change this.”

14.2.3.1 Norwegian Deck cadet:

“My opinion of the method is that it reveals many specific effects of the sudden failures.”

“This method does not reveal easily enough the barriers and their effects. By reading between the lines one might understand where the barriers are placed.”

“My overall impression of the method is that it gives a specific understanding of the critical components of the equipment. It is easy to find a failure, and follow the free to find the fault.

This method serves more as a result method, than a preventing method. Often used after the failure have happened."

"As explained, I feel that barriers have been left in the shadow, and needs more light. In the illustration the barriers could be marked in some way, which easily warns the users what to inspect."

14.2.3.1 Norwegian QHSE Manager:

"I believe the example needs to be more detailed in order for a person to be able to make full use of this method.

Even more tedious and time consuming than FMECA."

"The effect of a failure is not addressed other than it may lead to the top event. Other consequences are not explored (however may be handled as another top event).

A description of each component, barrier etc. must be added as the tree itself does not present these."

"I believe it will handle large systems, but it may be easy to lose track.

For large systems I rather prefer the tabular approach as it gives a better overview.

I think it will be better for smaller systems, as it may very fast become overwhelming for large and complex systems."

"Only addresses the top event. Must be repeated for each possible event (or consequence).

As it uses a top-down approach the undesired event and all contributors to the failure must be forseen.

Also, The method is only as good as the people performing the analysis."

"The method does not allow for describing barriers to the same degree as the FMECA. However if performed correctly, barriers will be added to the tree."

"I like the top-down approach as it makes you explore different routes that may cause the event.

However I fear that this method will be way too tedious to be usable for the Company (PSV).

It needs some additional information in order for all the "ISM-boxes" to be ticked. Hence it cannot be used alone."

"Would be good in combination with another method. But again that would make it extremely time consuming."

14.2.3.2 Norwegian Senior QHSE Advisor

"This method only present the faults of a system. It doesn't present any barriers directed towards these faults. It doesn't either include any information regarding consequences (injuries, materials, environment and so on), other than the main event placed at the top (Davit failure: Lowers uncontrolled). In general, the method does not give a good and easy understandable presentation of the system being analyzed."

"The method does not determine the criticality of a system, only a set of potential fault paths."

"Very poor. The method only identifies faults that might lead to the top event (davit failure). It does not at all display any information regarding effects this might have on surrounding equipment and technical systems."

"Used as a method, based on ISM 10.3, the fault tree analysis is not suitable. It gives you very little information beyond a combination of faults that might lead to a top event."

14.2.3.3 Summary

The common feedback is that this is not a perfect method. It might be usable on smaller systems, and if it do work on larger systems that are more complex might the result be hard to follow.

The majority feels that the effect of a sudden failure is not provided, which is correct as the FTA only concern the chain leading to the sudden failure.

The chief engineer states that he feels the progression of the flowchart is the wrong way. There is no law against it, but the common norm is to present the flowchart the presented way. This illustrated how different theory and practice may be as it in theory "is just that way", but the practical worker cannot see the logic and percept the whole thing as messy. Nobody else in the expert panel stated the same, but if the panels was enlarged is it reasonable to think that someone else would agree even if they don't say it out loud.

14.2.4 ETA

14.2.4.1 Danish chief engineer:

"The method is easily understood by the shown example. The true/false structure of the system is very straight forward to understand Even to someone who does not have a lot of knowledge about the given system. The steps taken seem to be in a very logical way."

"The method really doesn't help much to assess whether the equipment is a critical component. As it will only display the outcome of the initiating event. Looking at the outcomes for each of the branches of the tree, there are none that actually tells us that the equipment is critical.

So based on that the event tree analysis might be a fine method for demonstrating the possible outcome of an event, but it does not have the ability to determine if the equipment itself is critical."

"The method is usable on all equipment on board, as long as the goal is to find the possible outcome of a process. But I do not think that it can be used to determine if a system or any equipment is critical."

"This method would give the same result on other types of vessels, providing the FRC was positioned similarly. On ships with the FRC mounted at a comparatively low height above the water, the fall injuries that the crew could sustain would be lesser."

"I feel the method lacks in highlighting the possible effects on surrounding equipment and systems, but it does have a high focus on the crew."

"The method very clearly demonstrates the effect s of initiating one or more safety barriers.

The outcome of using the barriers either one by one or as a combination of more barriers is very clearly displayed in this method."

"The event tree analysis is easily read and understood, even for someone without a lot of experience or knowledge in that particular field.

But I feel that it is better suited as a teaching tool than for a method of investigating if equipment is critical."

"The method is very logical in its construction, but from my point of view, it focuses more on the event than on the equipment. I have no suggestions to how this might be altered."

14.2.4.1 Norwegian Deck cadet:

"This method should fit any equipment and technical system. It would be difficult to implement this method on large and complex system, as the illustration also becomes large, since the illustration shows exponential outcomes. This method would fit small systems very good, as it is easy to read and follow."

"My opinion of the method is that it reveals many specific effects of the sudden failures."

"This method reveals the barriers and its effect on each other. Which easily shows the user that a failure in one of the barriers would increase the probability to create dangerous situations."

"My overall impression of the method is that it gives a specific understanding of the critical barriers of the equipment, and also the different outcomes of the failures. One downside is that the illustration of the method would easily become large, because of the exponential chain of events, and therefor would only fit small systems."

14.2.4.1 Norwegian QHSE Manager:

"Good description. Easier to "get right on with it" than with FTA. "

"A description of each component, barrier etc. must be added as the tree itself does not present these.

I dont believe it is directly appliccable to all systems with respect to the ISM code requirements.

Again only one event is analyzed at the time."

"I believe it will work well for stand-by systems, but not necessarily for all on board systems.

I think it will be better for smaller systems, as it may very fast become overwhelming for large and complex systems."

"Only addresses the initial event. Must be repeated for each possible event.

Also, The method is only as good as the people performing the analysis."

"I guess identifying the barriers is exactly what this method does."

"Does not alone ensure compliance with the ISM code. Must be used in combination with other methods."

14.2.4.2 Norwegian Senior QHSE Advisor:

"This method only displays the event itself (davit lowers FRC uncontrolled) and the barriers and potential consequences of the event. It does not give any information on causes leading to the initiating event."

"It can be done, but would be very challenging as you are only presenting one "cause" at a time. E.g. as seen in the example "brakes fail, true or false". More complex system would have many potential "causes" for each initiating event. Identifying all these and the other pivotal events and presenting them by using an event tree analysis would most likely be very challenging and time consuming."

"Some barriers are presented in the pivotal events section, such as "area not secured" and "crew without immersion suits". In theory, several more barriers would have some sort of effect on this system, preventing the davit to lower the FRC uncontrolled, such as proper maintenance routines, procedures for launching, etc."

"My impression is that this method is not suitable for identifying critical equipment in acc. with ISM 10.3."

14.2.4.3 Summary

The experts agree that this method is not the best either. It is understandable, but for a larger equipment or technical system will the flowchart soon become unreadable and hard to keep track of. As the previous methods does this neither tell us directly if the equipment or technical system is critical or not.

The information provided is limited as the method does not give any reason for the event, just the barriers and possible outcomes. As mentioned when analyzing the method is there at this case also several more barriers and possible outcomes so the method will have a hard time at a relatively simple equipment or technical system.

It is proposed that this method could be a good learning tool instead of an analytical method. An interesting thought that not all would have brought up. It is reasonable that it could provide a better understanding of the possible outcomes of different events and present the necessity of barriers such as PPE and other safety equipment. That could make it easier for a trainee or student to visualize the whole thing better without experiencing such situations. Of course, the analytical part must be removed and the analysis performed in a way that is understandable for persons without any experience in order to perform as wanted.

14.2.5 The B. Apperry Method

14.2.5.1 Danish chief engineer:

“At first the method seems a bit unclear due to all the arrows and the comparatively little tex. But after looking at the flowchart for a couple of minutes it suddenly becomes very clear. At that point the method becomes very easy to understand and the template/flowchart makes perfectly sense.

The definition of the groups and their criticality seems very logical; this is probably due to the author having been at sea, so the frame of reference is easily understood by other seafarers.”

“The Apperry method doesn’t seem to take into account that while a repair job might be possible, it is still not certain that this is a real solution. If the davit fails and it is needed immediately to launch the FRC to retrieve people from the water, it is of little interest that we can perform a repair job, because we would need the davit immediately.

This should perhaps be mentioned somewhere regarding the specific equipment that there is a given time limit too that needs to be taken into account.”

“This method would be usable on all technical systems on board, as long as the systems would fit into one of the defined groups.

But since the groups cover essential equipment/systems for the ships safe function, any equipment that would not fit into these groups is by definition not critical equipment. ”

“This method does not reveal the possible effects on surrounding systems .”

“The method does not give any information regarding barriers meant to degrade the hazardous situation.

There is no need for further explanation of the effect of the system, since it seems that this is not the intended scope of the method to give such.”

“If the phrase “ABANDON SHIP” is substituted with “CRITICAL EQUIPMENT”, it can be used immediately to recognize critical components/equipment or systems on boars a ship.

For such use, the flowchart it is a great little tool that could be easily explained to people trying to compile a list of critical equipment. It is my impression that it would yield very similar results if more people were asked to use it on the same system.”

“If used for the basic function to assess whether a component is a critical component or not, this flowchart is hard to beat.

It doesn't describe any possible outcomes of failures or barriers, but it seems extremely well suited to define if a component can be regarded as being critical for the operation on board."

14.2.5.1 Norwegian deck cadet:

"I feel that this method is hard to understand, but the sub chapters describes the most important to fully understand the method"

"This method should fit any equipment and technical system, as it only gives a general result of the criticality."

"My opinion is that this method does not reveal any specific effects of sudden failures. It rather gives the required action to a sudden failure."

"This method reveals only the general barriers, such as maintenance, repair and assistance. Any specific barriers to the equipment is not displayed."

"My overall impression of the method is that it gives a loop of actions to follow if a sudden failure occurs."

"The way the method is built, it can't become more specific, and it would be difficult to make it any better."

14.2.5.2 Norwegian QHSE Manager

To the question whether clarification was needed but not made visible due to the setup of the method:

"Not so much your description as the method itself. I have seen this method described before and must admit I don't get it."

" To be honest- even with an IQ which allows Mensa membership, I don't get it!"

"Does not provide a structure approach.

Does not really give an ansver to what is critical with respect to "sudden failure"."

"In my view it is a load of crap that entirely misses the purpose of the ISM code."

14.2.5.3 Norwegian Senior QHSE Advisor*:*

"In my opinion this method is not feasible. The method does not include a good overview for all the different components/systems analyzed and this would make it challenging when making use of the results from the analysis afterwards. Also, by not making use of a perspicuous table/figure set up, analyzing more complex systems by making use of this method would most likely be very time consuming."

“The barriers are presented in the “Specific measures” part. Each barrier is explained quite good. However, I feel that the presentation of the barriers is not good. I would prefer a table overview which would give a better overview and would make it easier to identify the link between the specific failure, effects of the failure and the barrier itself. “

“My overall impression is that this method is not feasible for performing an analysis of an entire vessel. The results of such an analysis would contain too much text, and would be very challenging to make practical use of.”

“By including a table/figure overview in the presentation of results. This would make it much easier to perform the analysis itself and to present/make use of the results.”

14.2.5.4 Summary

One remark that came back from several of the experts was that they were missing a flowchart. The figure from Appery does not contain any of the information on the equipment or technical system, but will rather be a tool to remember the steps of the analysis.

To the question whether the method is usable or not are the experts divided in their opinion. The chief engineer did not understand it at first, but after reading it a time or two more did the purpose reveal itself and he feels the method is logical and clear. This is definitely not the case for the QHSE Manager that do not feel comfortable with the method at all.

14.2.6 The Ajabu Method

14.2.6.1 Danish chief engineer:

"I find the example used to demonstrate the method clearly understandable. The system is presented in a logic way, by both addressing worst case consequences and criteria for the event/system."

"I do not feel that anything needs to be clarified regarding this method. The method appears to be very thorough and covers all aspects."

"I believe this method is usable on all equipment and technical systems on board since it is so thorough.

Perhaps it would be a bit complicated for very simple systems, but it would be able to handle them. For large and complex systems / equipment it would work very well."

"This method would most likely give the same results from other types of vessels, with the very small exception that the relevant procedures might vary. The only reason this can be seen is that this method takes the relevant procedures into account and those procedures would naturally be different depending on the ship type and the shipping company.

But overall the results would be the same."

"I feel certain that this method will reveal all the possible effects that a sudden failure will have on surrounding equipment and technical systems. This is due to the fact that the flow sheet contains a dedicated section for "worst-case consequence"."

"The method displays all relevant information regarding barriers, ranging from the barrier itself to its effect and limitations. Thus the method provides a comprehensive description of this part of the equipment / system in question.

There is no need for any further explanation of the effect on the system."

"Overall I am impressed with this method. It provides the opportunity to focus on every aspect from criteria to procedures and barrier limitations to SFI codes etc.

The system gives the impression of being very well thought out and clearly suited for the maritime sector."

"It might not be the fastest or easiest method, but it will provide a very sound foundation for determining critical equipment.

If this method is used, it seems to me that it will also make a fine tool for use in the HSE work on board. E.g. when new equipment is installed on board and procedures and safety measures regarding this equipment needs to be discussed.”

14.2.6.1 Norwegian Deck cadet:

“This method should fit any equipment and technical system. It would fit for a small system, and for larger systems.”

“My opinion is that this method does not reveal all specific effects of sudden failures. It rather gives the worst case scenarios, and the criteria for these scenarios to be fulfilled.”

“This method reveals a very good representation of the barrios, and also the limitation of the barriers.”

“My overall impression of the method is that it gives a good representation of the worst case scenarios, criteria for these to be fulfilled and the barriers. In a way it is a very general representation, but still get to include many criteria and barriers.”

14.2.6.2 Norwegian QHSE Manager:

“Good description. Easy to “get right on with it”.

It is nearly self-explanatory.”

“I dont really get the worst case scenario thing.”

“I believe it “ticks all the boxes” of the ISM code, and is subsequently detailed enough.

Method seems to be an adaption of the FMECA which is better “fit for purpose” for the application on a PSV.

I do not believe it is too detailed for simple systems (it will only be less time consuming).”

“The method is only as good as the people performing the analysis.

Also using only one worst case scenario may cause other possible consequences to “be lost”.”

“I like the fact that is also addresses limitations in barriers.

Allows for “Human factors”.”

“I believe this method ticks all the boxes of the ISM code, while at the same time providing a structured approach and a result that gives a good overview and explanation for the reader.

I like tha column for reference to relevant prodedures.

I also like the fact that it distinguishes between safety and environment.

I also like the column with criteria where the circumstances for the effect are addressed."

"The column for relevant procedures can be ammanded with "relevant work orders" (from PMS) as well.

Maybe a pre-defined set of consequences considered "critical" can be added where the user can just tick off (instead of the worst case scenario)."

"My definitive favorite!"

14.2.6.1 Norwegian Senior QHSE Advisor:

"At first glance it is not possible to determine the probabilities related to each of the failure modes. However, a seafarer or anyone with maritime competence would be able to sort out the more likely failure modes and criteria's based on experience. However, some probabilities could have improved the totality of the Ajabu flowsheet."

"I believe this method could be used on all equipment/systems onboard. The failure mode section can be adjusted to the type of equipment/system you are analyzing, making it possible to include as many or as few failure modes as relevant. More complex systems will have a higher number of failure modes, but the table used in the Ajabu method allows you to include each of them and all the relevant information (criteria, consequence, barrier)."

"The method itself doesn't focus on revealing possible effects of sudden failure on surrounding equipment/systems (no headlines or sections of the table has included this option). Revealing such effects will be dependent of the competence/experience of the person performing an analysis by making use of the Ajabu method. The table itself, the evaluation of barriers and consequences allows you to gather and present a lot of information, and effects on surrounding equipment/systems could be included here."

"To a high degree. Barriers are included in the flowsheet, and are further analyzed in section 3.5.1.7 and 3.5.1.1."

"My overall impression is that this could be a good approach to use when analyzing critical equipment onboard ships."

14.2.6.2 Summary

The experts agree that this method is understandable and will work good for the purpose of being in compliance with the ISM 10.3.

They notice that the connections to other equipment or technical systems is not visible. This is an important part of the analysis and must be included in the best possible way.

The proposal from the QHSE manager “Maybe a pre-defined set of consequences considered “critical” can be added where the user can just tick off (instead of the worst case scenario).” is good and should be considered.

Overall does it seem that this is the method with most positive feedback among all.

14.2.7 Those not responding to all methods separately

14.2.7.1 Polish chief engineer

"Use of commonly known equipment help to understand represented methods. Illustrations are second helpful mean."

"There is no need for any more explanations on any of presented methods."

"I think, all methods can be used on all technical systems and equipment. More complex systems or equipment may require, analysis is break into parts, but still it should present useful result."

"In my opinion, all presented methods will be useful on any type of vessels, including: bulk, container, product carriers, ro-ro and offshore. Any kind of the vessel will have critical components, and to identify criticality and required measures, one of presented method should be used, going through whole ship."

"In my opinion, not any of the method, but person who carries analysis assures all problems are identified. Most effective would be analysis by team of persons with different background, than completed analysis should be open for verification based on feedback from crew."

"Same as above, method itself will do not recognize all barriers. It is assessor and further feedback from operation, that assures success."

"Text is quite interesting. Methods are nicely presented."

"All methods are generic and will require individual approach, during analyses."

"Ajabu method, worst case scenario is very surprising. I would expect personal injury at sea as worst case. Intentional operation of FRC at port with davit over quay is very unrealistic and I will very hardly dispute, this is worst case.

Personally, I will prefer Apperry's method. This seems to be most simple and focus on equipment type. However using that method, it can miss some issues.

Event tree and fault tree are good to identify all risks, but can grow into too complex graph.

FMECA should give similar overview as both, event and fault trees, but are easier to study and analyze due table layout."

14.2.7.2 Anonymous #1

The first anonymous did answer the questions asked in some way, but did also explain how #1 though of the greater picture and how #1 has experienced this on board.

#1 believes to be representative for people with common position and feels that the crew on board has a good overview of the critical equipment or technical systems, even though it is not written exclusively for that purpose. Having an overview would probably make follow-up easier and could easily be linked to maintenance planning.

#1 found the methods generally understandable, but very theoretical presented.

The mariner states that what is found critical on a PSV does not necessarily have the same criticality on another type of vessel. this will depend on the type of vessel and the given equipment or technical system.

Anonymous #1 choose the B. Apperry method as a favorite since it seems "very practical and good. He states clearly what criticality is."

If the risk acceptance criteria is stated well enough will several of the methods be usable, but for now is it only the Apperry method that includes this well enough in the method.

14.2.7.3 Anonymous #2

"I find the presentations of the method understandable in all of the examples, but on the Ajabu method I got somewhat confused by the description and I felt that the composition of the text was lacking somewhat the flow of the other examples. Which led to multiple re-readings.

The part that affected my opinion the most was a combination of the clarity of the illustration (easy to see what was displayed and not needing a spyglass) and the direct approach of the writing, this approach made it easy to see the connection between text and illustration and made it easy to follow the writers "thoughts"."

"I think the method is not usable on all equipment on board, because the process of analysing each act will demand one person to work only on analysing full time. And there will always be the possibility of something unforeseen will happen that haven't been analysed. Of course there could be developed an database for certain operations but there could be individual characteristics for the event that can't be applied to the database."

In what degree do you feel secure that this method reveals all possible effect the sudden failure may have on the surrounding equipment and technical systems?

"To a relatively good degree, it covers all likely events that can be expected in the operating of the equipment"

"I feel that the implementation of the barriers is not explained, and it is not clear whom is supposed to say yes or no to the operation been seen through."

“My overall impression is that the writer has knowledge in the areas that are in question. And have done extensive research to back up and enforce the knowledge. There is good flow in the text and the reader is captured and led through the text with precise and direct information that mostly covers the areas that the reader needs to understand the text and corntext. The writing is in a language and stage of advanced/terms that is fit for reading for both the ones with special education and the “average joe”.”

“The combination and explanation of the methods makes a good and complete picture to the reader.”

14.2.7.1 Anonymous #3

“On a scale from 1-6 : 4 I find the example pretty good, and the ilustrations give a good degree of understanding. ”

“I think this method is usable, but I still find the methods quite complicated and I am still looking for a simplified way of explaining and addressing this onboard to the mariners and the vessels superintendents. It is important that this does not become overcomplicated and theoretical.”

“These methods should work on the type of vessels I have worked on, large cruise ships and naval ships.”

“I think the method displayes enough information about the barriers, but a simplified explanation of effect of the system would be an advantage. It is important to understand who the users are, On a scale form 1-6: 4”

“Very good description of methods, but I would prefer a simplified method that is easy to understand for the users. On a scale from 1-6 : 4.”

“Remember the users , keep the methods and explanations at the right level directed at the end users.”

14.2.7.2 Summary

It is hard to understand which method they refer to at all times.

The chief engineer present his opinion on each of the methods in the end and indicates that the Ajabu method would be his first choice.

As seen in the feedback from those dividing their answer to each method is the use of illustrative flowcharts and simple approach a common statement.

15 Conclusion

Analysis of methods both from the author and from expert panels has now been presented and the time has come to make the recommendation of the best method.

15.1 Recommended method

The Ajabu method was developed in order to be the most suitable method, which I feel is achieved to some point. The experts panels seem to agree to this and the FMECA as the best methods. Since the Ajabu is designed based on the FMECA with improvements towards the maritime and TOAS norms is the Ajabu method the method I would like to recommend to TOAS to be used on their vessels to comply with the ISM Code paragraph 10.3.

Based on the feedback on that method and other methods has some improvements been done. As presented on Figure 26- Improved Ajabu method (Løvmo, 2016) has two more columns is added to ensure the possible connection to other equipment or technical systems is identified. The first of those columns shall contain the SFI code to all equipment or technical systems that in any way provide information, support, signals, etc. to the analyzed equipment or technical system, and the other will contain the SFI code for all equipment or technical systems that receives the mentioned from the analyzed equipment or technical system.

I believe that out of the five methods presented in this thesis is this the overall best method. Some of the others might score on some points, but then again fail at others. The Ajabu method was easy to alter so that the largest drawback was eliminated. It could be further coded so that colors appear in the cells when you write a certain word, and the SFI codes can be linked so that it is possible to jump between analysis and in that way follow the whole chain a system is part of.

15.2 Observations made during the process

The number one observation from the feedback was that visualization by use of diagrams or flowchart was highly appreciated, both for the fresh mariners and for those with almost a lifetime at sea. This supports the theory that one has to make the method understandable for all readers and that a combination of text for those who wants to know the details and a visualization for those who wishes the quick answer is favorable. If the method is intricate would the visualization also be a tool for all to keep track of the written text while reading.

Some information about the different methods was excluded from the presentation sent to the experts in order to not guide them in any direction. If they knew that a method only was intended to perform under certain settings could this lead to them deem it from the start and not analyzing it at all. Another thing that was not revealed for the expert panels was the risk acceptance criteria. This might have been a risky idea, but the criteria is one of the cornerstones of the analysis and I wanted to see if anyone noticed that they saw equipment being categorized without knowing where the limit was placed. Some, for example #1, noticed this one or more times and said this made the method somewhat unclear.

SFI Code	System/Equipment	Failure mode	Worst-case consequence	Criteria	Initial consequence level	Criticality	Barrier	Barrier effect	Barrier limitation	Final consequence level	Relevant procedures	Systems connected to current system	Systems connected from current system	Comments
501.10.01	FRC Davit	Lovers uncontrolled	Trauma or fatalities	Crew in FRC	Safety		None	None	There is no other access points to the FRC other than when hanging alongside in garage.					
					Environment		None							
				Persons under FRC	Safety		Procedures for securing area below FRC	If performed will criteria be eliminated.	Time and recources needed.					Not Infallible.
					Environment		None							
				Davit failure	Safety		Maintenance and inspection	Expand lifespan and safe operation	Will not inhibit aging, weather, wear etc.					
					Environment		None							
		Does not lover	Evacuation, SAR and transportation disabled	Evacuation needed	Safety		No crew on board, flooding pumps, fire inhibitors etc.	Inhibits evacuation need	Not able to eliminate all situations					
					Environment		None							
				Person or object in water	Safety		Railing, safety harness,	Reduce risk of falling into water	Human error, fault in equipment					
					Environment		None							
				Other means of evacuation available	Safety		Dacon Scoop, ladder, gangway etc.	Eliminate the need of FRC	Weather dependent, vessel not always in port					
					Environment		None							

Figure 26- Improved Ajabu method (Løvmo, 2016)

16 Future work

Obviously, feeding all the equipment through the method will be part of the future, at least if TOAS chooses to follow my recommendation.

Before that can take place should the method be stress tested on large and complex equipment or technical systems in order to discover failures, weaknesses or other things that could be corrected before the real analyzes are initiated to avoid moving back and forth between analyses along the way to correct them one by one.

The data presented must be further confirmed before implementing any method. The expert panel is not large enough to be representative to the population of mariners and shipping company staff, even if they feel they are representative themselves. In order to find the answer to which method mariners find most suitable must a larger group be addressed and provided more examples on each method.

Some of the responses came very quickly. It is of course possible that those persons obtain information easily and do not need more time to understand the methods presented to them, but the chances are that they also did not use enough time to process it all. They were not given that much time either (two weeks approx.) because the author wanted to be sure that their answers came in after she had completed her analysis so that they did not affect her opinions.

The fact that only the davit was tested is a quite large drawback as we have no proof whether the methods will work on “any” equipment or technical system available on a modern PSV. Even if it has been theoretically compared to an ECDIS analysis is this not a validation, just an expectation made by the author that has limited knowledge about the specific ECDIS used on Arcturus.

This thesis has not focused so much on the last part of the paragraph 10.3, even if the procedure-section in the method can be interpreted as provided specific measures. This, and a link between the method and the testing plan must be established to fulfill the whole paragraph. Adding one more column stating how often the given equipment or technical system should be tested is one way of doing that.

Last, but not least, one has to remember that this is a living document. Whenever equipment or technical systems are modified must the analysis also be modified. When new equipment or technical systems are added must they be analyzed and put in connection with whatever they give or receive any information with. As the method also refers to internal procedures at TOAS must these connections also be kept living.

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18 Appendix 1

This appendix contains the information that was presented to the expert panels on the different methods. If one compare it to the previous walkthroughs of said methods is it mostly the same text. Improvements has been done as to present the methods so objectively that it would not be clear in any way other than the experts opinion if the method is usable or not. Some wording is also changed to be sure that all understand the method.

18.1 Email text

The below text was stated in the email and the rest of chapter 0 was added as a PDF-file.

"Good evening everyone,

I will soon be handing in my master's thesis and must therefore test my hypothesis. To do this I need assistance from an expert panel, and I hope you would like to be a part of this.

My thesis will be me recommending a method that is "the best" for deciding whether equipment or technical systems on board a vessel is critical or not. I will be looking at five different methods, some well tested and some without documented testing, and then compare them towards each other in order to determine which is the most usable.

I hope that you could be so kind to help me by reading through the attached document and answer the questions on the last pages. You will be one of my expert panels, the other will be office staff here in Tromsø. When I receive your feedback will this be evidence to prove or disprove my hypothesis. The goal is to demonstrate the different methods and I'm fully aware that there must be technical mistakes and really lousy language in more than one of the paragraphs. I hope you can survive despite these flaws.

I think that all you need of additional information is included in the attached document, but please feel free to ask if there is something that is unclear. All feedback is good feedback in this case, so additional remarks is highly appreciated.

It is completely voluntary to participate and I would appreciate it if you let me know as soon as possible if you wish to contribute or not. I need a certain number of participants so if you decline I need the time to find somebody else. If you are on board and someone else there wants to try will that be much welcomed.

Have a great evening ☺

God kveld alle sammen,

Deadline på masteroppgaven min begynner å nærme seg og jeg må i den forbindelse teste min hypotese. For å få det til trenger jeg hjelp av et expertpanel og jeg håper du vil være en del av dette

Oppgaven går ut på at jeg skal anbefale en metode som vil kunne brukes til å bestemme om utstyr og tekniske systemer om bord i et fartøy er kritiske eller ikke. Jeg tar for meg fem forskjellige metoder, noen godt utprøvde og noen spesialiserte som det ikke finnes dokumentert bruk av, som jeg da sammenligner mot hverandre og derfra avgjør hvilken jeg mener er den beste.

Jeg håper dere kan hjelpe meg ved å lese gjennom det vedlagte dokumentet og gi meg tilbakemelding på spørsmålene bakerst. Dere vil være det ene ekspertpanelet, det andre består av noen av ansatte her på kontoret. Når jeg får tilbakemeldingene inn vil disse bli benyttet til å bekrefte eller avkrefte min hypotese. Poenget er å demonstrere metodene, så jeg er klar over at det som står under enkelte metoder kanskje er teknisk feil og at språket enkelte steder også er labert. Håper dere holder ut likevel.

Jeg tror det dere trenger av ytterligere informasjon finnes i det vedlagte dokumentet, men det er bare å spørre om det er noe dere lurer på. Dere får også lov å komme med ytterligere tilbakemeldinger dersom dere ønsker.

Dersom dere ikke ønsker å delta håper jeg dere kan si ifra så raskt som mulig. Jeg må ha et visst antall deltakere så dersom du ikke ønsker å delta må jeg se etter en annen person. Dersom du er om bord nå og noen av de rundt deg også ønsker å delta er det helt i orden.

Ha en strålende kveld ☺

Med vennlig hilsen/ Best regards, “

18.2 Introduction letter

Dear ladies and gentlemen,

I write to you because I am conducting a master's thesis in "Technology and safety in the high north" and need your assistance. I am trying to determine which method is the best in order to analyze equipment and technical systems on a PSV in a way that makes it possible to determine if such is a "critical" equipment or technical system.

The need for such method is found in the ISM code § 10.3:

"The company should identify equipment and technical systems the sudden operational failure of which may result in hazardous situations. The SMS should provide for specific measures aimed at promoting the reliability of such equipment or systems. These measures should include the regular testing of stand-by arrangements and equipment or technical systems that are not in continuous use."

My evaluation of which method is the best will be based on my education, but I have no practical experience from vessels and this is where I call for your assistance. I ask you kindly to read through the methods presented and answer the questionnaires attached in the end.

When sending yours answers to me please state if you allow me to quote you or not. If you not will be quoted, but replies with very good feedback I will only use your rank to separate the quotes. There are several people with the same position asked so if all decline quoting will age or nationality be added so that I can keep the quotes from each other.

Your replies will be used to prove or disprove my hypothesis that states which method is best.

It is completely voluntarily to participate and there is no lower or higher limit on how much you can answer on each question. You can answer by writing in a document or in an email, just make it clear which method and question you are answering. Please let me know as soon as possible whether you want to contribute or not, as I will search for other participants if you decline.

Please also ignore the language and sometimes lack of technical knowledge about the system. You are the experts here and I will try my best to make it better before handing the thesis in. The text is written so that non-maritime people should be able to understand the most of it. Therefore might texts that you find unnecessary be elaborated to avoid misunderstandings.

18.3 Chosen equipment

Among all possible equipment and technical systems was the FRC davit on Troms Arcturus chosen. This because it is a relatively simple system, Arcturus has a special type of davit and because the author could in some way relate to this so that performing adequate analyses was possible.

An FRC (Fast Rescue Craft) is a small vessel, typically under ten meters, that is commonly used for collecting objects from the sea or other tasks that requires a small vessel with good maneuverability and high speed.

Figure 27- Mare Safety GTC700-2VD (Maresafety, n.d.)

The FRC Davit (hereafter davit) is located approximately amidships on Arcturus' port side in a garage. The davits task is to hold the FRC steady while not in use and to launch the FRC controlled when needed. One may look at it as a crane that is specially designed for this task. To launch the FRC will the crew lead the davit holding the FRC first in lengthwise direction to get into a position where the ships side below the FRC is as straight as possible, and then perpendicular to this motion to lead the FRC outside the shipside. Before this last motion shall a protection wall be lifted up and reveal a hole in the ships side for the FRC to get through. The wall's rupture strength is lower than the force the davit will use in the perpendicular motion and therefore will the davit be able to break through the wall if this is stuck in any way.

The FRC is a Mare Safety GTC700-2VD with LOA of 7,18m and breadth 2,85m (maximum). It is produced in aluminum, weighs 2630kg and has a normal speed between 20 and 40 knots.

The davit is an Aukra Maritime AMTDT-3700 with a SWL of 3700kg and normal lifting/lowering speed of 0-50m/min. It can operate safely with a 20 degree list and 10 degree trim. The temperature range for safe operation is -20 to 40 degrees Celsius.

The davit will launch and retrieve the FRC when a hydraulic controlled winch is operated. This winch and the two drive gears used for traveling gets their hydraulic power from an integrated power pack that is mounted on the davit itself. To operate the davit may the crew choose between a control station or a remote (handle). The power pack consists of the tank containing fluid and an electric motor that drives the pump. For monitoring and safety is an oil level glass, breathe filter system, drain valve, full flow return filter and main safety pressure valve installed.

Brakes is also installed and they will be able to stop a fully loaded FRC combined with the dynamic forces that might be present if it starts falling. The brakes should also stop the FRC immediately if the hydraulic forces decrease as a result of a broken pipe or similar.

Figure 28- Troms Acrturus (Tromsoffshore, n.d.)

18.4 Methods

18.4.1 FMECA

18.4.1.1.1 Introduction

The Failure Mode, Effect and Criticality Analysis is a technique commonly used to identify, prioritize and eliminate potential failures in a system, design or process. It is often used as a precautionary analysis to identify weak systems or equipment in the design phase in order to improve them before they are taken into use.

System: FRC Davit Troms Arcturus						Performed by: Signy Anita Løvmo					
Ref Drawing:						Date:					
Description of unit			Description of failure			Effect of failure					
Ref No	Function	Operational Mode	Failure mode	Failure cause or mechanism	Detection of failure	On the Subsystem	On the system function	Failure rate	Severity ranking	Risk reducing measures	Comments
SFI 501.10.01	Safely lower and raise the FRC	Lower, rise, standby, test.	Moves uncontrolled	Broken wire, signal fail in remote/ control station, load limit exceded, brake fail	Inspection or in operation	Physical damage to FRC	System does not perform as expected, system might get further damaged.	Unknown	Catastrophic	Inspection, maintenance, procedures for launching the FRC	If the davit fails may crew get injured and evacuation /SAR/ transportati on/ collection/ inspection inhibited.
			Does not move	Oxydation, brake fail, ice, power break	Inspection or in operation	FRC can not perform as intended	Entire system not functioning.	Unknown	Catastrophic	Inspection, maintenance, extra power supply, heating	

Figure 29-Failure Mode, Effect and Criticality Analysis flowchart (Løvmo, 2016)

Above is a picture of the completed general FMECA analysis form. One can make changes in the layout to fit the equipment or technical system better.

18.4.1.1.2 Definition and delimination of the system

The system is an FRC davit as demonstrated in Chapter 12.1.1

18.4.1.1.3 Definition of the main functions of the system

The system shall store, launch and retrieve the FRC. Each task shall be performed safely, at different times and only when the crew initiates the given task.

18.4.1.1.4 Description of the operational modes of the system

Standby: the davit holds the FRC steady in the crib while it is not in use.

Operation mode 1: Moving lengthwise and sideways to position the FRC outside vessel. Lower FRC safely when operation initiated.

Operation mode 2: Lifting FRC safely from sea surface and maneuver back into standby position.

18.4.1.1.5 System breakdown into subsystems that can be handled effectively

The FRC is a subsystem of the davit. If the davit fails may it cause severe damage to the FRC. Protective layers might get scratched, which is a minor damage, or the FRC might hit the sea surface with such force that it breaks.

The winch, the power pack and the control station is more directly subsystems that, unlike the FRC, will be able to cause the failure of the davit.

The crew is not looked upon as a subsystem, but rather as the users of the system.

18.4.1.1.6 *Review of system functional diagrams and drawings to determine interrelationships between the various subsystems*.

No drawings or diagrams exists at this point.

The system is quite small and isolated, and contains only the parts mentioned in 12.1.1 plus a number of pipes, hoses and joints.

18.4.1.1.7 Preparation of a complete component list for each subsystem

In this case will the FRC be looked upon as one subsystem, even if it is an assembly of several parts. This is because the physical trauma or limited function to one of these general parts will make an impact on the total subsystem when it is initiated from a davit failure.

The winch, the power pack and the control station will also be three components despite the fact that they all is an assembly of several components. This because that detail level will be sufficient to demonstrate the method, but please be aware that a complete component list will be possible to put together.

18.4.1.1.8 Description of the operational and environmental stresses that may affect the system and its operation

In operation will wave hitting to the hull of the FRC possible be great enough to, over time, make the materials tired. The FRC can move in high speed and the force on the hull will be greater by each knot. This might lead to and easier fraction force if the FRC should fall freely at a davit failure.

The davit will repeat the same movements every time it is operated. Joints will wear and demands regular maintenance.

Cold temperatures will make materials crispier and allow them to break easier. Hydraulics will also run slower and may therefore create a slowness or malfunction in the system. Icing might be able to lock parts that in operation is supposed to move, or in worst case intrude into pipes or cracks and break them.

18.4.2 Fault tree analysis

18.4.2.1.1 Introduction

One of the most common method in risk and reliability studies today is the Fault Tree Analysis. It was invented in 1962 by Bell Telephone Laboratories and later improved by the Boeing Company that also introduced computer programs that could handle both quantitative and qualitative FTAs. The analysis will result in a diagram that displays the relationship between a potential critical event and its cause.

On the next page is a simple way to illustrate a FTA shown. We see the top event, the davit lowering the FRC uncontrolled, which may be a reaction to three different events. It may in real life certainly be more than three events, but these three has been chosen to illustrate how the analysis is carried out.

Each of those three events will be initiated by three main causes, which all occur as a result of three triggering factors. Notice the OR-gate, this indicates that the triggering factors must not occur all at the same time in order to create the main cause. Only one is necessary to initiate the event, but if more than one occur will the result have the potential to be even more destructive.

18.4.2.1.2 Define the issue and the boundary conditions of the system you wish to analyze.

The issue in this analysis is the davit lowering the FRC uncontrolled. Uncontrolled means that it lowers too fast, in fits and starts, free falling, or at the wrong time. The analysis shall identify what can cause such behavior.

For some equipment and technical systems will there be tens of different causes for a failure. It will be too time consuming and heavy to present them all here as the focus is on the method itself. Those conducting a full analysis in the future shall make their own decision on how many, if not all possible, causes shall be included, but for this demonstration will three events with three main causes that again has three triggering factor each be the limit.

18.4.2.1.3 Construct a fault tree.

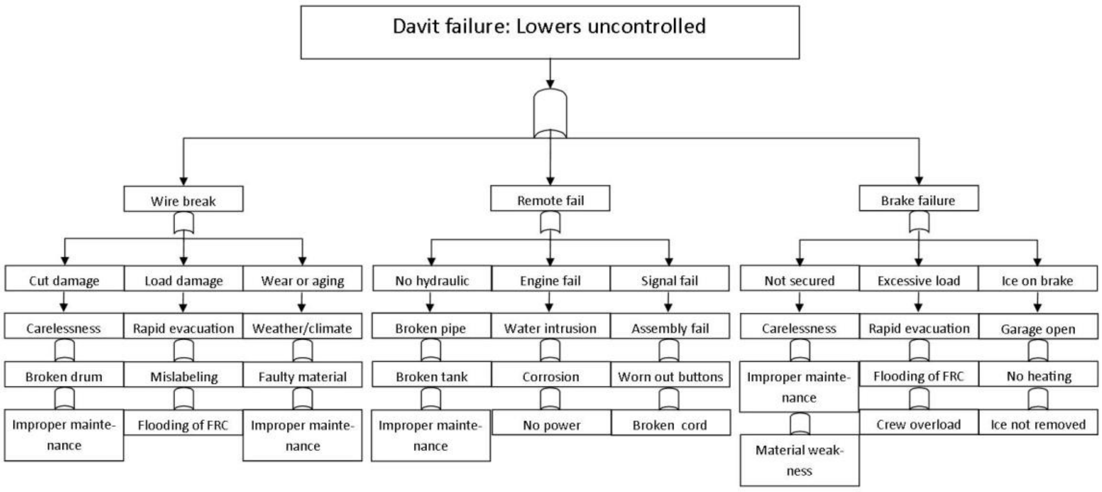

Figure 30-Fault Tree Analysis flowchart (Løvmo, 2016)

18.4.2.1.4 Identify minimal cut and/or path sets.

This FTA is quite simple and the minimal cut set is a constant of three. For the davit to fail must one of the three events occurs and they each needs only one main cause to do so. Each of the main causes needs just one of the listed triggering factors to occur, even though the frequency might increase if several appears at the same time.

18.4.2.1.5 Perform a qualitative analyze of the fault tree.

One can conclude that human error and improper maintenance is root causes that in many ways can result in a hazardous situations. In the example shown above will improper maintenance be possible triggering factors for all three events, which again often is a result of human error. The same can be said for several of the other triggers. A proactive and well designed maintenance plan will be one step on the road to secure the reliability of the system.

Outer factors such as temperature, humidity, strokes and weather will have an impact on the failure probability and must be evaluated when materials and design is chosen.

18.4.2.1.6 Perform a quantitative analyze of the fault tree.

No data available and calculations is therefore not performed.

18.4.3 Event tree analysis

18.4.3.1.1 Introduction

The Event Tree Analysis starts at the initiating event, and then demonstrate the possible outcomes. One of the benefits with this analysis is that it includes the barriers that may stop or mitigate the chain of events. The ETA is commonly used in the design phase to visualize the effect of different barriers and showing the different chain of event that forms when the barrier is function or not.

18.4.3.1.2 Identification of a relevant initiating (accidental) event that may give rise to unwanted consequences

In one way may the actual need of the davit to lower the FRC be an initiating event. If the need is not present, the davit will not be able to fail in any other way than letting the FRC move in the garage in heavy seas. We read earlier that the initiating event should be "The first significant deviation from the normal situation that may lead to a system failure or an accident.", so the need of the FRC cannot alone contribute to the hazardous situation of a davit failure. The use of the FRC can also be seen as normal operation as it will be tested regularly and used for non-emergency operations from time to time as well. The sudden davit failure, on the other hand, will create a better initiating event as the elevated hazard for the crew will start at that point. Normal operation is as safe as one can tolerate if all procedures and conditions are considered and treated.

18.4.3.1.3 Identification of the safety functions that are designed to deal with the initiating event

Brakes are installed and shall be able to immediately stop a fully loaded falling FRC.

To ensure that there are no persons below the FRC that will be injured if it should fall down should the boatswain at least visually inspect the below area before moving the FRC outside the vessel.

To protect themselves in normal operation as well as emergency shall the crew in the FRC wear an immersion suit or other clothing that will keep them dry and warm. This clothing will keep them from hypothermia both when the sea is splashing around the craft and if they should end up in the sea.

18.4.3.1.4 Construction of the event tree

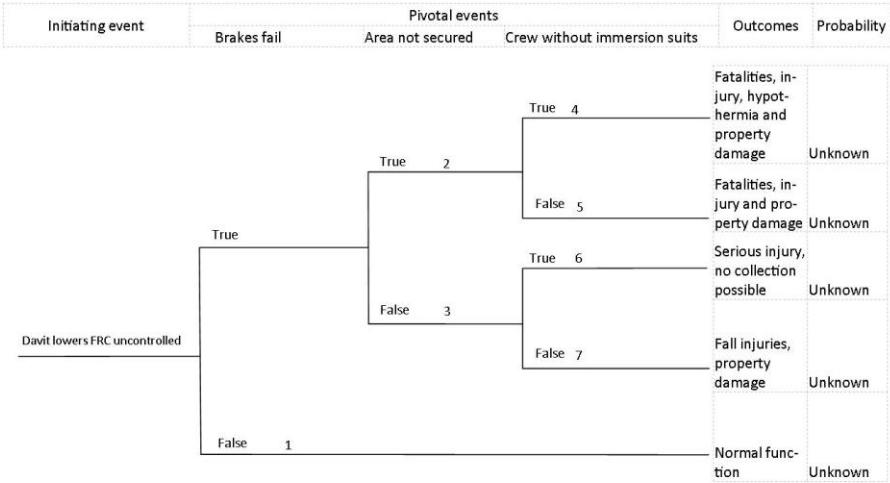

Figure 31-Event Tree Analysis flowchart (Løvmo, 2016)

18.4.3.1.5 Description of the resulting accident event sequence

On the figure above is all the possible paths numbered and they will now be described.

In all seven situations will the risk of falling from the FRC be present. This might be caused by slippery footing, negligence or misstep, as well as a human reaction to movement or fear.

1. The davit will lower the FRC uncontrolled, but the brakes work, the area is secured and the crew wears appropriate PPE. This means that all the barriers function and they will stop and mitigate the situation.
2. The davit will start lowering the FRC uncontrolled and the bakes has failed so that these cannot stop the downwards motion. The area below is not secured so the falling FRC will be of danger to both the crew on board the FRC and those potentially beneath it.
3. The davit will start lowering the FRC uncontrolled and the bakes has failed so that these cannot stop the downwards motion. The area below is secured so the situation will only be dangerous for those on board the FRC.

4. The davit will start lowering the FRC uncontrolled and the bakes has failed so that these cannot stop the downwards motion. The area below is not secured so the falling FRC will be of danger to both the crew on board the FRC and those potentially beneath it. The crew is not wearing correct PPE and the risk of hypothermia is raised.
5. The davit will start lowering the FRC uncontrolled and the bakes has failed so that these cannot stop the downwards motion. The area below is not secured so the falling FRC will be of danger to both the crew on board the FRC and those potentially beneath it. The crew is wearing correct PPE and the risk of hypothermia is decreased.
6. The davit will start lowering the FRC uncontrolled and the bakes has failed so that these cannot stop the downwards motion. The area below is secured so the situation will only be dangerous for those on board the FRC. The crew is not wearing correct PPE and the risk of hypothermia will increase.
7. The davit will start lowering the FRC uncontrolled and the bakes has failed so that these cannot stop the downwards motion. The area below is secured so the situation will only be dangerous for those on board the FRC. The crew is wearing correct PPE and the risk of hypothermia is decreased.

18.4.3.1.6 Calculation of probabilities/frequencies for the identified consequences

There are no available data on this and calculation is therefore not possible.

18.4.3.1.7 Compilation and presentation of the results from the analysis

From the tree above is it visible that the criticality is exponential. As soon as the brakes fail will injuries be a possible outcome and the more barriers that fail the more severe may those injuries be.

The fall injuries will depend a lot of how the fall turns out. The human body is not symmetrical on all axes and therefore will some ways to hit the sea surface have a greater potential of creating trauma than others.

The immersion suit does not guarantee that the person wearing it survives, but it will increase the probability by approximately three times when focusing on hypothermia. It is estimated that a person will survive in the North Sea for about 30 minutes without proper suiting, and around one and a half hour with this suit on. Of course, this is very dependent on the person, the weather, the temperature and other circumstances, but it gives some understanding of which role the suit may have. Because of this are we not able to conclude on any certain difference between scenario 4 and 5, just assume that the probability for greater hazards exists in scenario 4.

All in all is there several “if-s” that can influence the consequence of each path, but there is also possible to see clear differences in the possible outcomes when the barrier is functioning or not.

18.4.4 The B. Apperry method

18.4.4.1.1 Introduction

One method that did show up when searching the internet for already used methods designed with The Code in mind was this designed by Bertrand Appery.

Appery is a member of the International Institute of Marine Surveying with "General and container cargoes" and "State or government surveys" as his fields of expertise. He wrote his article describing the method in 2007 as a result of his experiences as a master mariner and discussing the IMS 10.3 with his colleagues. He had then been at sea for most his life, of which more than 20 years as master mariner.

Firstly, Appery define that these groups of apparatus or systems are required to perform when the vessel is in operation:

- Propulsion, navigation and their management
- Port operations; manoeuver and commercial operations
- Power and its management
- Permanent safety; detection, lighting and eventually automatic fire extinction
- Response elements; extinction, fire or drainage pumps
- Survival; abandon, search and rescue

Appery chose to define the level of criticality based on which measures that is initiated to ensure the safe operation of the equipment or technical system.

- Critical without redundancy nor procedures of replacement
- Critical with procedure of replacement
- Critical with redundancy
- Critical with redundancy and procedure of replacement
- Not critical

18.4.4.1.2 Description of equipment or technical system

Description of davit is found in 12.1.1.

18.4.4.1.3 Level of criticality

The davit may fail to function completely, which will inhibit the use of the FRC. This may again inhibit evacuation, collection of objects and SAR, which all primarily is performed in order to save lives.

This davit might also fail in performing its tasks correctly. One example is that it moves the FRC in the garage or outside the ships side to rapidly or too slow. If it moves to slow will the planned operation take longer time, which might aggravate the situation if the operation is evacuation or SAR. If it moves too rapidly might crew or items on board the FRC loose balance and fall, either into the FRC or over board into the water. This is also critical as injuries of different levels has great potential of occurring.

Based on this will the davit be in the category “Critical with redundancy and procedure of replacement”.

18.4.4.1.4 Specific measures

- Redundancy: having two or more davits and FRCs will provide an alternative if the first fails.
- Reinforced maintenance or more frequent tests by ship’s crew: will increase lifespan and reliability of the davit.
- Periodical control by specialized company: they should be able to spot weaknesses and early wear that the crew on board is not trained to do.
- Spare parts: limited space on board will decrease the number of spare parts to a minimum. Small components that can be used all over the vessel such as hoses, couplings, nuts etc. is a minimum. There will not be possible to have a complete davit in spare parts stored on board.
- Familiarization and preparation of the ship’s crew: all on board should have enough knowledge on the system to be able to step in and assist if some or all of the designated operators is enabled.
- Special training for operators: those operating the FRC shall be specially trained in using the davit as well. They will be able to see the use of such technical system in a practical matter and might therefore be able to react early if something goes wrong.

18.4.4.1.5 Replacement procedures

- Hand drive operation on the spot (installed).
- Emergency power or fuel supply.

18.4.4.1.6 Risk analysis and operation in degraded status

The level of criticality is high as it may lead to any level of injury or even fatalities. The fact that the davit is part of a barrier itself will increase the criticality, and in this case is it easy to spot such connection. It might be harder in more complex systems, therefore is good knowledge of the analyzed system required to perform a good analysis.

One can see that measures that can increase the reliability exists. Some, such as maintenance, training and monitoring is relatively easy to implement. Others, such as keeping spare parts on board is possible to a certain level. Big and expensive elements will often not be ordered until they are needed, both since they will take up unnecessary space on board and because few will use money on an item they don't need in the foreseen future, especially if they can take other measures to prevent the situation.

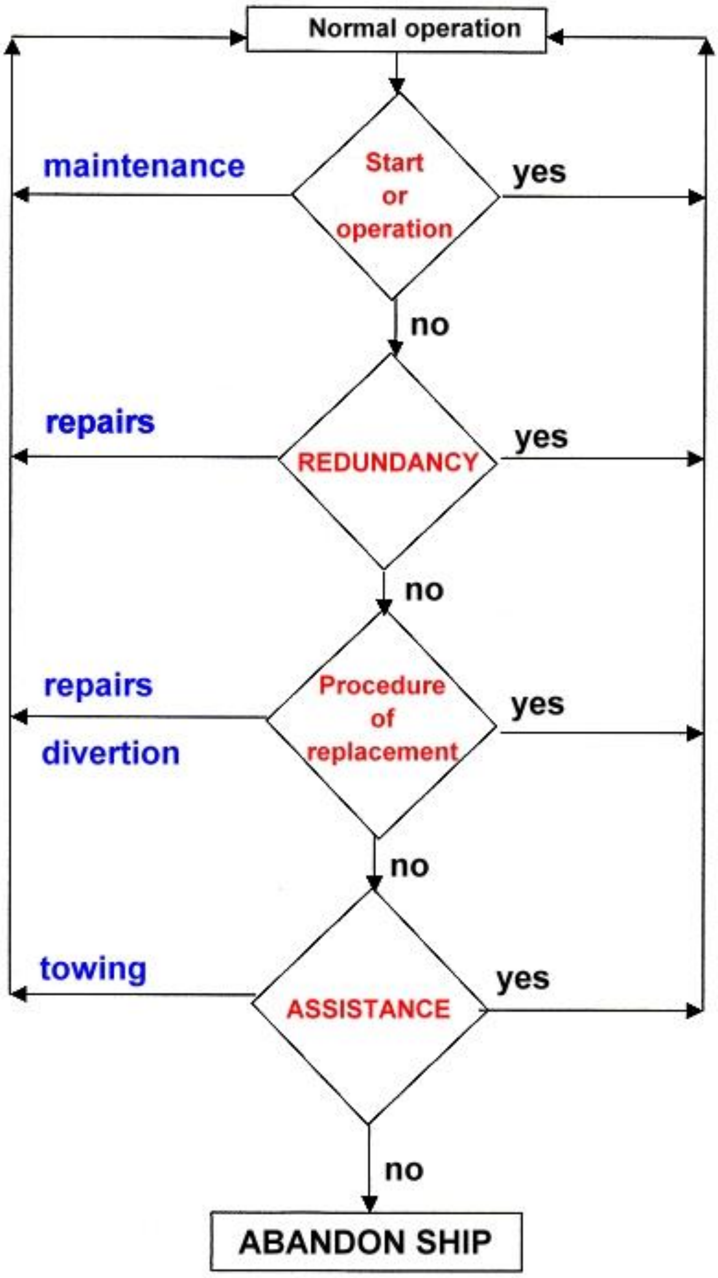

Figure 32- Apperry's operation flowchart (Afcan, 2007)

18.4.5 The Ajabu method

18.4.5.1.1 Introduction

Another already existing method of analysis is the Ajabu method. Tasnifu Ajabu and his brother Ndugu both works at the University of Cape Town where they are contributing to The African Urban Risk Analysis Network. In 2011 were they contacted by a group of shipping companies that found it difficult to interpret the ISM 10.3 and to know if they were in compliance with it or not. The shipping companies and the Ajabu brothers cooperated close for nearly a year to develop a method that satisfied both the ISM and the mariner's needs.

18.4.5.1.2 *A brief introduction of the equipment or technical system*.

The davit is introduced in Chapter 12.1.1.

18.4.5.1.3 Scenarios.

The davit fails in two way:

c) it lowers the FRC uncontrollably
d) it does not lower the FRC at all

In both cases is it given that the davit is at a position where the FRC hangs outside the railing at the same height as the deck in the garage. If the FRC is in its initial position will scenario a) be inhibited by the davit and scenario b) be the intended event.

18.4.5.1.4 Consequences.

18.4.5.1.4.1 Situation a

If the FRC lowers uncontrollably, will the worst case scenario be that it with all its crew falls onto a quay full of people. The result may be serious injuries or fatalities.

An uncontrolled lowering of the FRC can be with or without persons inside the FRC. If there are no persons on board may the hazards include damage on FRC, damage to Arcturus, loss of FRC, parts/wire in the propellers of Arcturus, damage to objects located below the FRC and the hazard of not having an FRC available. If there are persons on board may there, in addition to the previously stated hazard, also be a threat to their physical and mental health, and their life. The people in close vicinity that observe this situation may also get injured, either by flying parts or mentally by witnessing the event.

18.4.5.1.4.2 Situation b

Scenario b) have two worst case scenarios: the crew cannot use the FRC for evacuation and the crew can not use the FRC to collect an object from the sea. The position of the FRC is not of any significance unless it is between the garage deck and the sea surface.

A fail in the lowering procedure may be discovered by inspections, at drills or in an emergency. If the FRC cannot be lowered may there occur an increased life-threatening situation for a person in the water, for crew trying to evacuate the Arcturus, or persons in fleets waiting to be towed or collected.

If the davit is unable to move along the rails so that it get is the release position may the main hazard be that the FRC will have the possibility to act as a pendulum if the Arcturus is rolling in the sea when launched. As shown on Figure 9- Troms Arcturus (Shipspotting, 2014) does the ships side curve towards the centerline below the initial position of the FRC, while the ships side is straight at the launching position.

SFI Code	System/Equipment	Failure mode	Worst-case consequence	Criteria	Initial consequence level	Criticality	Barrier	Barrier effect	Barrier limitation	Final consequence level	Relevant procedures	Comments
501.10.01	FRC Davit	Lovers uncontrolled	Trauma or fatalities	Crew in FRC	Safety		None	None	There is no other access points to the FRC other than when hanging alongside in garage.			
					Environment		None					
				Persons under FRC	Safety		Procedures for securing area below FRC	If performed will criteria be eliminated.	Time and recources needed.			Not Infallible.
					Environment		None					
				Davit failure	Safety		Maintenance and inspection	Expand lifespan and safe operation	Will not inhibit aging, weather, wear etc.			
					Environment		None					
		Does not lover	Evacuation, SAR and transportation disabled	Evacuation needed	Safety		No crew on board, flooding pumps, fire inhibitors etc.	Inhibits evacuation need	Not able to eliminate all situations			
					Environment		None					
				Person or object in water	Safety		Railing, safety harness,	Reduce risk of falling into water	Human error, fault in equipment			
					Environment		None					
				Other means of evacuation available	Safety		Dacon Scoop, ladder, gangway etc.	Eliminate the need of FRC	Weather dependent, vessel not always in port			
					Environment		None					

Figure 33- Ajabu flowsheet (Løvmo, 2016)

18.4.5.1.5 Criteria.

18.4.5.1.5.1 Situation a

To be in a position where the worst case scenario may happen a series of conditions must be fulfilled:

6. the vessel is alongside at port
7. the FRC is partially launched
8. the crew has entered the FRC
9. people are standing beneath the FRC
10. the davit fails

If one or more of these is removed, will the hazard be reduced or eliminated.

18.4.5.1.5.2 Situation b

To be in a position where the worst case scenario may happen a series of conditions must be fulfilled:

6. There must be a situation that requires an evacuation
7. There must be crew that needs evacuation
8. Cross on dry land evacuation is not possible
9. There must be a person unintentionally in the water
10. Conditions inhibits use of ladder or dacon scoop to get person out of the water

18.4.5.1.6 *Evaluation of initial consequence picture*.

18.4.5.1.6.1 Situation a

The situation has potential of resulting in serious injuries or fatalities.

18.4.5.1.6.2 Situation b

The situation has potential of resulting in serious injuries or fatalities.

18.4.5.1.7 Barriers.

18.4.5.1.7.1 Situation a

6. Being in port will eventually happen and is a part of the duties of Arcturus. Therefore can it not be any barrier to stop this event.
7. Launching the FRC is necessary to obtain duties, to drill and for inspections. Therefor must this action be initiated from time to time, but not necessarily while at port. This situation can be eliminated in certain circumstances.
8. The deck is too high above the sea surface for it to be safe for the crew to enter the FRC from there at all times. It might be a possibility to use a ladder if the sea and weather is on the good side, and one has time to do it that way.
9. People standing beneath may easily be eliminated by closing of a certain area on the quay. This is a simple measure that will eliminate the hazard for injuries or death on non-crew.
10. It will be impossible to eliminate a davit fail entirely, but the probability may be reduced by correct use of the equipment, correct and thoroughly planned maintenance, condition monitoring, regular testing and environmentally adaptive measures.

18.4.5.1.7.2 Situation b

8. Such situations may be fire, water intrusion, loss of stability, grounding or serious illness. All which have a low likeliness due to procedures and testing, but none of them can defined as completely improbable.
9. As long as the vessel is in a normal working situation will there always be crew and other people on board. The number will change if she is carrying clients, passengers, her normal number of crew, or if she is at port so that visitors also can be present.
10. If the vessel is at port will it be possible for the crew to walk from the vessel to a safe location. When at sea will dry land evacuation be possible if the weather- and sea conditions allow a safe transfer from Arcturus to another vessel on the sea by use of a ladder or by evacuation into a fleet without getting in the water in advance.
    It is not practical possible to keep the vessel in port at all times, as she would not fulfill her purpose as a vessel. The weather is neither possible to control at any time.
11. By "unintentionally" is people, such as surface swimmers and divers, who are in the water to perform a job excluded. To avoid falling into the water should prevailing safety measures be initiated. Safety harnesses and rope should be used when working in areas that may allow a fall into the water. In winter shall precaution be shown to icing on the vessel and gangway, as well as if spills on deck occurs.
    The risk of human error and "bad luck" will be major in this event. Therefore will it be impossible to totally eliminate it, but correct behavior and understanding of the job and circumstance will help lowering the risk majorly.
12. The use of a ladder or dacon scoop will eliminate the risk of the crew that maneuvers the FRC at all times, but there is not always possible to use those solutions. The person in the water has to be conscious and able to think and move in the water. He might be too cold to have the necessary motoric function and consciousness to move himself close to the vessel and/or climb the ladder. The weather and/or the sea might also be too rough for a person to move controlled in the water. The person must not hit into the vessel and, more important, not get run over. This might be hard to avoid when the sea is rough and the vessel should in this case move slowly away from the person. There will be possible to send a skilled swimmer into the water connected to the vessel with a rope or a wire. He may then swim to the person and keep a tight grip on him as the rest of the crew pulls them both towards the dacon scoop and lift them into the vessel. Again, the weather is uncontrollable and even if the vessel position

herself in a way that provides shelter for the person is there no guarantee that the person is in a condition that allows him to use the ladder or deacon scoop.

18.4.5.1.8 Evaluation of overall consequence picture.

Some of the criteria that must be fulfilled for the worst case scenario to be possible can be eliminated, but not all. The consequences is also shown to fit as critical according to the definition. Therefore is it not correct to say that the hazard the use of this equipment can be eliminated by procedures, training and maintenance.

18.4.5.2 Measures that can be taken to reduce hazard

A maintenance plan suited for the specific vessel/ vessel type and her crew is to recommend. In this way will there be a uniform understanding among the crew how the procedures shall be completed and what aids are available to execute such operations.

If there are any special equipment (such as an FRC and not a MOB-vessel) will there be essential to train the crew on given vessel in operating and understanding this equipment instead of providing a brief overview to all crew in the fleet. In an emergency will each crewmember hold a designated role on board and is expected to be able to perform in both perfect and horrible conditions. If a person has a complete understanding of how the davit and the FRC works will he be able to understand possible underlying causes of a fault and therefore be able to identify the risk of them happening before they actually occurs. He will also have a better opportunity to solve any problems that may occur when the FRC is on the sea.

On Figure 34- Troms Pollux with garage closed and Figure 35- Troms Pollux with garage open, we see clear pictures of the FRC and davit garage on Troms Pollux. Arcturus has the same garage with a protection wall, which protects both the davit, the FRC and crew against weather and sea. Salt water sprayed on the equipment may lead to corrosion on the equipment and the fabric drying out on the FRC. The plastic screen may also lose its transparency. These hazards will decrease the lifespan of the equipment and demand a greater frequency of maintenance, which both are expensive and time consuming.

The wall has a rupture strength that is lower than the force the davit can launch the FRC. In other words is it possible to break the wall by force if it should not open as supposed.

Since there shall be possible to transfer people to and from the FRC while it is alongside hoisted up is there no railing on this part of the deck. If there is heavy weather and the vessel is rolling may there be a great hazard of crew falling down in the sea if the wall is not present. The crew shall evaluate the prevailing circumstances and decide if harnesses and safety ropes shall be included as a part of the protection equipment for crew working in the area.

18.4.5.2.1 Additional information.

Physical and mental damage shall be considered the most hazardous consequence of a davit fault. There is no guarantee that those damages can be healed, and there is no way of determine the time it will take to heal if such is even possible.

After the hazard to humans should the environment be considered. The most environmentally hazardous situation will be if the FRC and/or davit falls into the sea. Both is made of materials that is not easily degradable and may cause harm for a long time. The davit has so high density that it will sink almost immediately and may be found and collected later if the depth make this possible. If is stays on the sea bottom it may be a problem for dredgers, fishing vessels and vessels anchoring in the area.

Hydraulic oil may leak out into the sea and be of danger to fish, birds, other animals living in the sea and secondary feeders such as humans. Parts of the FRC is made of a material that has such density that it may float below the sea surface for a long time. It may be eaten by larger animals, get stuck on animals or degrade into smaller pieces and be swallowed so that it cause harm to the smaller animals' digestive system.

The economical consequences may in some cases also be evaluated. The equipment itself is expensive and will lead to an unnecessary cost to replace. If another vessel is harmed, either directly by the FRC falling onto it or indirectly by the vessel getting parts into the propellers, there might be an insurance matter that may lead to a considerable cost to the shipping company. This will lead to loss of income and a poor reputation of the vessel and shipping company.

Economy and criticality should only be in the same sentence when the level of criticality determine how much one shall budget to ensure the reliability, never in order to estimate the criticality in a way that justifies the budget.

Figure 34- Troms Pollux with garage closed (2013)

Figure 35- Troms Pollux with garage open (2011)

18.5 Feedback

Please answer the questions on the following pages for each of the methods based on your own thoughts and ideas.

If you prefer to use a scale when appropriate, please use grading from 1 to 6 where 1 is very poor and 6 is excellent.

18.5.1 General questions

1. How representative for other persons in the same rank do you see yourself?
   - Will a random person in the same rank with another experience, education from another country, different length of service be likely to return the same answers as you? Where do you think the differences will become visible?

2. In what way do you think an overview of critical equipment will influence your job?
   - Have you experienced any situation where you could have needed it or when you think it would have made your task easier?

18.5.2 Questions

1. In what degree do you find the example used to present the method understandable?
   - What affected your opinion the most? (Method template, the chosen equipment, language and way of writing, illustrations, other, or a combination of two or more?)

2. Is there anything you feel needs clarification that this method cannot display in any way?
   - Details that should be there to provide better understanding, but these have no natural place in any of the subchapters.

3. Do you believe that this method is usable on all equipment and technical system on board a vessel? Why/ why not?
   - How do you think it will handle larger and more complicated systems? Will it be too detailed to work on very simple equipment and technical systems?

4. If you have previous experience from other types of vessels, do you believe that this method will provide the same result for equipment and technical systems on that vessel?
   - Please also state type of vessel.

5. In what degree do you feel secure that this method reveals all possible effect the sudden failure may have on the surrounding equipment and technical systems?

6. In what degree do you feel that the method displays enough information about the barriers that are, or may be, initiated to prevent or degrade the hazardous situation?
   - Do you feel the need for more thorough explanation of effect on the system, why it has been placed at the given location or other details?

7. What is your overall impression?

8. Can you think of any changes or additional items that could easily make this method better?

9. Any other comments or remarks?