FORMAL SAFETY ASSESSMENT OF OFFSHORE SUPPORT VESSELS

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ABSTRACT

Considering the expanding industry for offshore units, offshore support vessels are also in the trend of increasing. In this sense, more complex and more demanding technologies are emerging especially for new designs of these type of vessels. Therefore, it is of great importance to have a framework based on risk assessment. In the maritime domain, risk is evaluated within the framework of the Formal Safety Assessment (FSA) which has become an internationally recognized and recommended method. This article discusses methodological requirements for the risk perspective of offshore support vessels. A perspective that is proposed here considers risk as a set encompassing the following: a set of plausible scenarios leading to an accident, the likelihoods of unwanted events within the scenarios, the consequences of the events and description of uncertainty. For this purpose, we introduce a qualitative scoring system, and we show its applicability on an exemplary risk model for an offshore support vessel.

Keywords: Formal safety assessment; Risk analysis; Offshore support vessels, risk based framework; offshore

1. Introduction

It is a fair assessment to say that the development and improvement related to the technology and the welfare of people can be very costly in regard to safety and money-wise. Also, considering the environmental effects, especially in last 50 years, these all issues become concern to the society. More complex and more demanding technology will require more effort in regard to risk management and this situation becomes a problem to deal with. When we look at the maritime industry, we have an international organization named International Maritime Organization (IMO). In order to satisfy the need of the industry on risk management, IMO implemented such regulations. When the historical background of safety assessment has been checked, it is possible to go back until 1970s. A good starting point for safety assessments is Probabilistic Safety Assessments used in 1970s for nuclear industry. After that in 1970s and 1980s for chemical and offshore industry, QRA (Quantitative Risk Assessment), Seveso Directive and local regulations have been applied.

For shipping industry, first studies related to the risk assessment have been started in 1990s with UK House of Lords, Lord Carver Report in 1992 [2]. Following to the in 1992 MSC 62, in 1997 MSC 68 and 2001 MSC 74 has been developed by IMO accordingly. In present time, IMO's 5 April 2002 dated GUIDELINES FOR FORMAL SAFETY ASSESSMENT (FSA) FOR USE IN THE IMO RULE-MAKING PROCESS (MSC/Circ.1023, MEPC/Circ.392) -will be referred as Guidelines hereafter- has been developed. Following to the developed guidelines, 2005 Amendment (MSC/Circ.1180, MEPC/Circ.474) and 2006 Amendment (MSC-MEPC.2/Circ.5) have been developed accordingly. It is fair to say that FSA was introduced at MSC 62 in 1993 for the first time. At MSC 65, it has been decided that FSA is to be treated as a highly prioritized item on the agenda [4]. Followingly, as mentioned above, in MSC 74, interim guidelines for FSA has been developed. In order to promote Formal Safety Assessment and as well as risk analysis for dealing with more complex problems, as mentioned above, Guidelines for Formal Safety Assessment has been developed by IMO on [1]. Also, in 2012, IACS have put more attention to this topic and prepared a presentation regarding MSC 75 on [2].

In the same sense, on [3] Christos Alex Kontovas has been extensively studied Formal Safety Assessment with detailed explanation of all steps and pointed out critical points as well as possible future role of this method. On [4], Quen-gen F., et al., have studied FSA on the view of human error and a propose have been made in order to preventing human error in ship operations in 2005. In this paper, formal safety assessment has been carried out and an assumption method has been done to prevent human error. On [6], Akyildiz H. and Mentes A., carried out formal safety assessment analysis for cargo ships and extensively conducted a research with the combination of fault tree analysis. Therefore, this reference is very good application of combination of several techniques. On [7], IACS prepared a study regarding the preparatory step of general cargo ships which consists of detailed historical data of ship types, their accidents and risk and other relevant information regarding the first step of formal safety assessment. As it is fair to assume that without first step it is not possible to move further in FSA, this study provides very valuable information for everyone. On [8], a formal safety assessment has been carried out for contained ships by Wang J. and Foinikis P. on 5 January 2001 which is very detailed for fast and very busy container operations. On [9], a historical data has been presented by Clarkson for offshore supply vessel industry which creates this paper's historical data partly. On [10], annual overview of marine casualties and incidents have been given by EMSA which is also a valuable historical data to be used in step 1 in this paper. On [5] and [11] provided detailed information regarding historical data, expert opinions and the investigation analysis in order to understand the problem and help to proceed further into risk assessment with the application of FSA. The general point of view of this paper is to understand and assess the risks of outgrowing industry and operational phases of offshore supply vessels. Therefore, all these references have been carefully picked and a base have been formed in order to create this assessment.

Formal Safety Assessment (FSA) has been developed to help IMO decision making process and to make it more rational. While providing a such basis and support to decision making, it can be used to assess and as a result improve maritime safety, including safety of life, health, the marine environment and property. In this connection, FSA can be used as a tool to help in the evaluation of new regulations for maritime safety and protection of the marine environment or in making a comparison between existing and possibly improved regulations, with a view to achieving a balance between the various technical and operational issues, including the human element, and between maritime safety or protection of the marine environment and costs [1]. Additionally, recognized organizations can use this tool for the assessment of individual ship designs and also can be used together with ISM applications. As a result of this, decision authorities at IMO, using FSA, may increase effectiveness of regulations by considering maritime safety including safety of life, marine pollution and as well as cost related issues.

2. Generic Assessment of an Offshore Support Vessel

As a preparatory step and before going into Step 1 named as Hazard Identification (HAZID), we need to assign some information for preparation to next steps. In this context, we focused on Offshore Support Vessel as a generic case. In this regard, firstly we need to limit ourselves for operational assumptions. After this, it is important to define ship life cycle as well as related ship areas which consists of constant threat to safety of life, environment and property. This assumptions and assessment have been carried out by five steps.

For generic OSV, following assumptions are applied regarding vessel age.

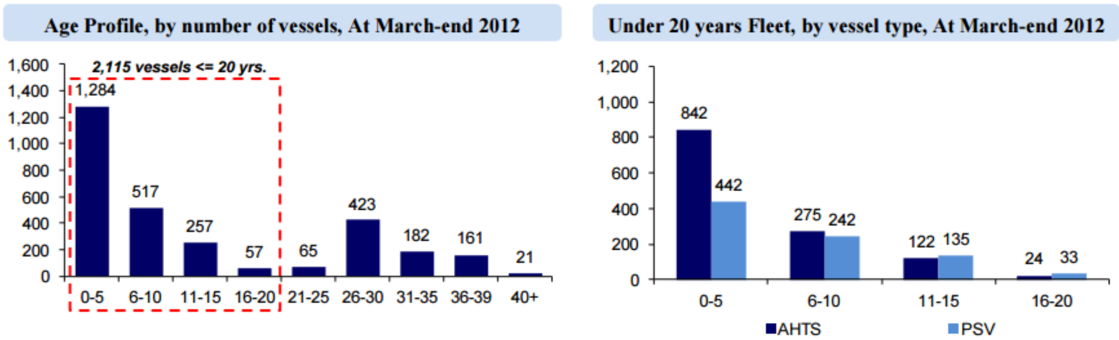

Fig. 1. Age profile of offshore support vessels [9]

As it can be seen above Fig. 1., approximately 70% of world fleet of OSVs less than 20 years old. Also considering the distribution of older vessels, it is fair to limit ourselves to 20 years of a lifespan for OSV accordingly. There is the first assumption; average lifetime assumed as 20 years.

In the world, we can define five major areas doing offshore for and thus in need of offshore support vessels or work vessels related to this area. These areas are US Gulf of Mexico, Europe North Sea, Asia Pacific Region, South America and Africa Region. Considering the workload, it is good assumption to have 330 operational days in a year. So, our average operational days per year assumed as 330 days.

Marine and as well as offshore industry are operating almost every hour of a day. Offshore platforms, support vessels, ports and relevant areas are always working. Therefore, operational number of hours in a day is 24 hours.

This is assumed as 2.5 years (or 30 months) in accordance with international regulations. Ships are subjected to docking survey every 30 months in connection with SOLAS therefore, 2.5 years' assumption is very realistic.

At this point, now it is important to define operational phases of an offshore support vessel in order to define and analyze the risks of a such phase. On this paper, we defined below given phases and followed accordingly.

1. Design/Construction/Commissioning
2. Port Operations (Berthing, Unberthing, Mooring Operations etc.)
3. Platform Operations (Maneuvering, Mooring, Lifting etc.)
4. Navigation
5. Other Operations (Lifting, Towing etc.)
6. Dry dock Maintenance
7. Decommissioning/Scrapping

However, it is important to adjust some of the operational phases due to low risk. When the historical records checked and as well as expert opinions asked, it is fair to assume that the 1st and 7th phases are bearing very low risk. Therefore, it is acceptable to omit these two phases. In this sense, risk assessment of offshore support vessels will have 5 phases accordingly.

3. Framework of Risk Assessment

After the identification of operational phases and assumptions of a life cycle for Offshore Support Vessel, base framework has been obtained for such vessel type. Now, it is possible and convenient to proceed step 1 of formal safety assessment (FSA). This paper's ship type is included in service ships as given below. Following assessment have been carried out for step 1 hazard identification. As for beginning of hazard identification, historical data has been examined. Below Fig. 2 accidents by ship category has been given. In Fig. 3, distribution of casualties by their type has been given. Another important data has been given in Fig. 4 which defines casualties for ships interacted with another ships. Considering this paper is based on OSVs, these kind of data is making the base point for hazard study.

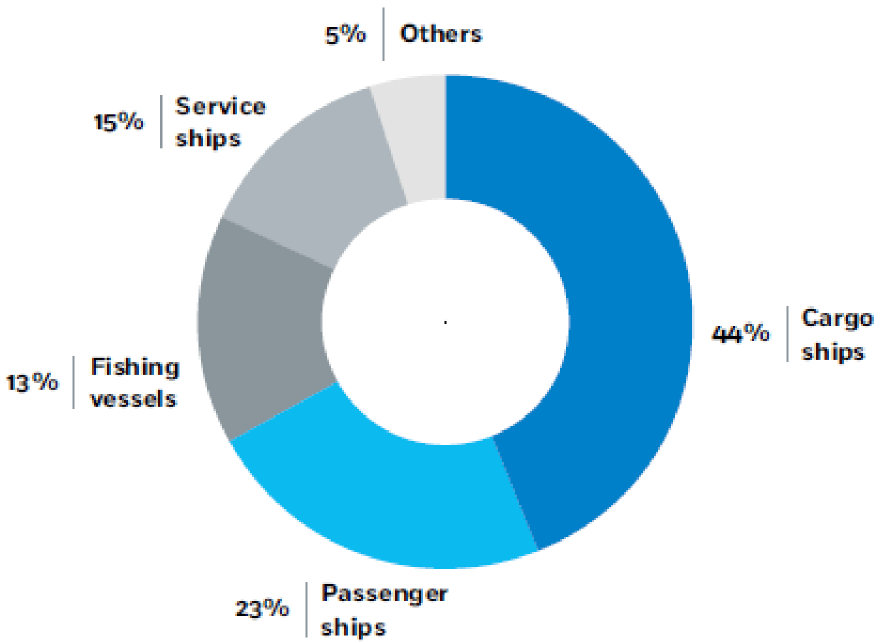

Fig. 2. Between 2011-2014 accidents by ship category [10]

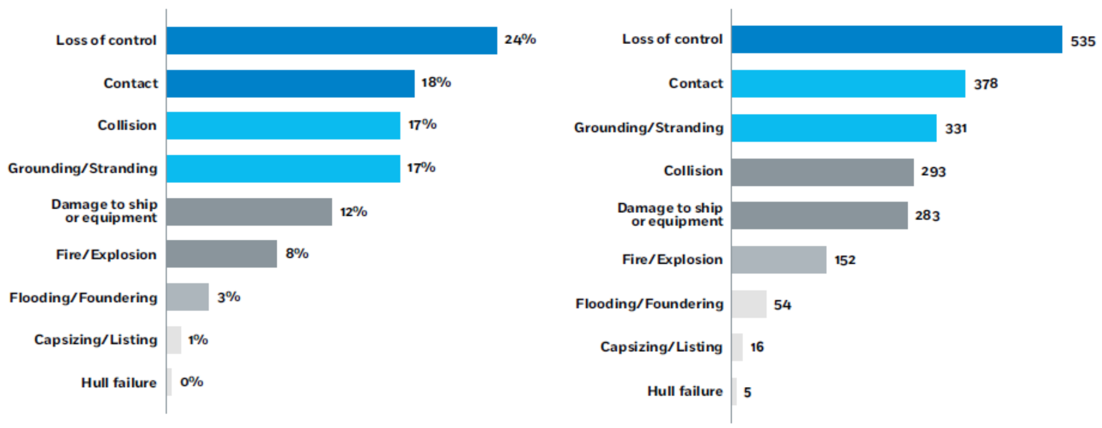

Fig. 3. Distribution of casualties and numbers [10]

At this point, the potential hazards are to be identified. For this identification, historical data, marine investigation reports, flag state information and other relevant reports have been checked. Many accident information and their detailed data for ship specific information have been taken from National Transportation Safety Board (NTSB) website [11].

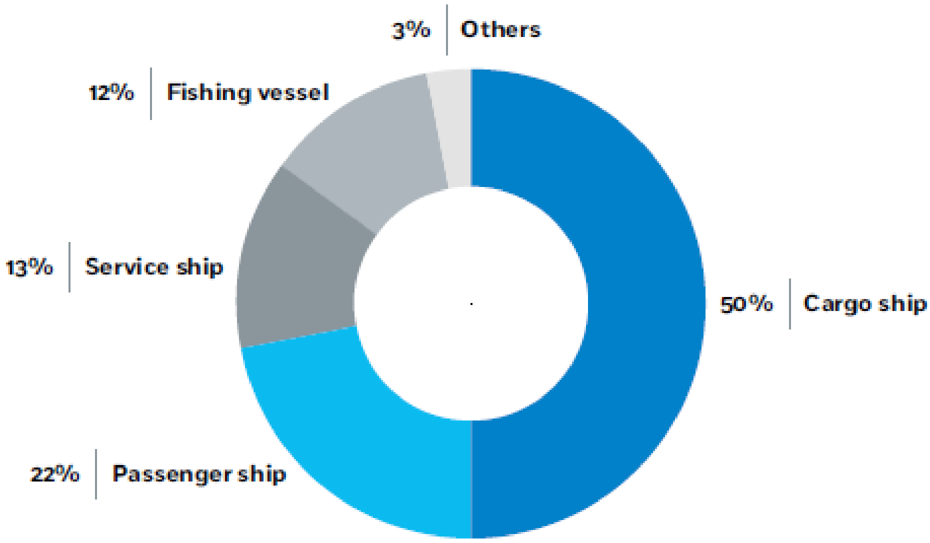

Fig. 4. Distribution of ships involved in a casualty with another ship

When the historical data has been checked for last several years, it is clear that the biggest accident type is collision/contact/allision. There also many fire/explosion cases, as well as capsizing, sinking and machinery failure incident too. Generally, following hazards have been defined.

1. Contact/Collision/Allision
2. Fire and/or Explosion
3. Grounding and/or Stranding
4. Flooding
5. Capsizing
6. Machinery Failure/Equipment Damage
7. Human Related Hazards (Electric Shock etc., Lifting Accidents etc.)
8. Material Failure
9. Others

At this paper, we have focusing on above Item No. 1 and No. 2. The reason is this selection is the identification of hazards of Offshore Support Vessels. As mentioned above, many accident/hazard types are collision.

As it can be seen that in the recent years, there are many hazards for collision/allusion. Also, Fire/Explosion is having very big numbers too especially when it depends on human error or machinery failure. Considering these damage and hazard types, as mentioned above, on this paper these two types of hazards are focused. After identification of hazards and as well as focusing area, it is time to sort the large amount of information to an accident sub-categories as follows.

1. Collision/Contact/Allision Sub-Categories
   - Equipment/Machinery Failure (Air leak, power failure etc.)
   - Weather Effects (Heavy swell, strong wind, fog etc.)
   - Maneuvering Failure (Loss of steering, navigational equipment failure etc.)

- Human Error (Lack of training, oversleeping, no watch keeping etc.)
- Mooring/Anchoring Failures
- High Traffic Density

2. Fire and/or Explosion Sub-Categories
   - Collision/Contact
   - Welding/Cutting Work
   - Human Error (Poor maintenance, bad operation etc.)
   - Equipment/Machinery Failure (Deck) (Fractured FO valve, electrical spark, leaks etc.)
   - Weather Effects
   - Equipment/Machinery Failure (Engine Room)

Considering these sub-categories, they are well decided together expert group and keep considering related historical data accordingly. Every sub-category is a reason which leads to a hazard in the past. Therefore, it is now good to move Step 2; Risk Assessment.

Step 2 risk assessment aims to carry out an identification and an investigation for the causes and results of the scenarios identified in previous step 1. To put it more clearly, risk assessment is a step to understand how the hazard in step 1 develop and cause an accident. In order to obtain possible outcomes, FTA, ETA and FMEA can be used. FTA distribution have been given in both Fig. 5. In our case, after risk assessment, FTA has been carried out both to assess risks in this step and in step 3 to understand cause-event chain items in order to proceed recommendations. In accordance with IMO FSA Guidelines, at this step now we are using ranking in order to define risks. See below Table 1 for detailed instructions of IMO FSA risk assessment. It is important to rank and prioritize identified hazards in step 1 in order to have a judgement on them. With this way, this gives an option to understand if identified hazard is minor or major. Deciding this, it is possible to have a more efficient outcome and this eventually affects the decision making process.

Table 1. Severity Index, Frequency Index and Risk Index assessment from IMO guidelines.

SEVERITY INDEX				
SI	**SEVERITY**	**EFFECTS ON HUMAN SAFETY**	**EFFECTS ON SHIP**	**S (Equivalent fatalities)**
1	Minor	Single of minor injuries	Local equipment damage	0.01
2	Significant	Multiple or severe injuries	Non-severe ship damage	0.1
3	Severe	Single fatality of multiple severe injuries	Severe damage	1
4	Catastrophic	Multiple fatalities	Total loss	10

FREQUENCY INDEX			
FI	**FREQUENCY**	**DEFINITION**	**F (per ship year)**
7	Frequent	Likely to occur once per month on one ship	10
5	Reasonably probable	Likely to occur one per year in a fleet of 10 ships, i.e. Likely to occur few times during the ship's life	0.1
3	Remote	Likely to occur once per year in a fleet of 1000 ships, i.e. likely to occur in the total life of several similar ships	10^{-3}
1	Extremely remote	Likely to occur once in the lifetime (20 yers) of a world fleet of 5000 ships	10^{-5}

RISK INDEX (RI)					
FI	FREQUENCY	SEVERITY (SI)			
		1	2	3	4
		Minor	Significant	Severe	Catastrophic
7	Frequent	8	9	10	11
6		7	8	9	10
5	Reasonably probable	6	7	8	9
4		5	6	7	8
3	Remote	4	5	6	7
2		3	4	5	6
1	Extremely remote	2	3	4	5

In accordance with commission experience and meeting as well as historical data and occurred accidents, ranking tables have been created as follows in Table 2 and Table 3. For both accident category, several RRNs have been on first priority. Considering all these effects into account, it has been decided to focus on "Human Error" for Collision/Contact/Allision sub category and "Equipment/Machinery Failure (Engine Room) for Fire/Explosion sub category. When the RRN numbers have been checked, these two have been identified as riskiest accident sub category. Together with these processes, also fault tree method has been used to complete step 2. FTA analysis for Human Error and Equipment/Machinery Failure (Engine Room) have been given in Fig. 5 and Fig 6. below.

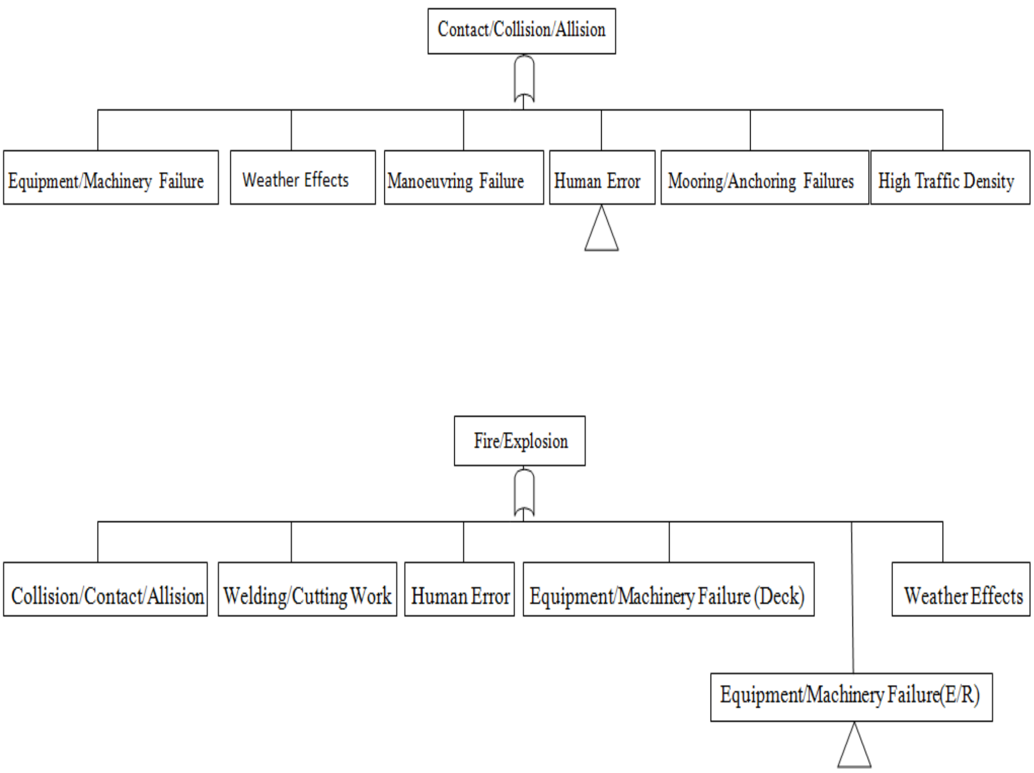

Fig. 5. FTA of contact/collision/allision category and fire/explosion category

Table 2. Collision/Contact/Allision Risk Assessment

Accident Sub-Category	Port Operations	Platform Operations	Navigation	Other Operations	Dry dock Maintenance
Equipment/Machinery Failure	F3S2=5	F4S2=6	F4S2=6	F4S2=6	F1S1=2
Weather Effects	F2S1=3	F5S3=8	F4S2=6	F3S1=4	F1S1=2
Manoeuvring Failure	F5S1=6	F2S3=5	F5S2=7	F4S3=7	F1S1=2
Human Error	**F5S2=7**	**F5S3=8**	**F5S1=6**	**F4S3=7**	**F1S1=2**
Mooring/Anchoring Failures	F5S1=6	F5S2=7	F1S1=2	F3S2=5	F1S1=2
High Traffic Density	F5S2=7	F2S2=4	F3S1=4	F3S2=5	F1S1=2

Table 3. Fire/Explosion Risk Assessment

Operational Area/Cause	Port Operations	Platform Operations	Navigation	Other Operations	Dry dock Maintenance
Collision/Contact	F3S1=4	F3S2=5	F4S1=5	F3S2=5	F1S1=1
Welding/Cutting Work	F2S1=3	F1S1=2	F1S1=2	F1S1=2	F5S2=7
Human Error	F2S1=3	F3S2=5	F3S2=5	F2S2=5	F6S2=8
Equipment/Machinery Failure (Deck)	F4S1=5	F4S1=5	F1S1=2	F4S1=5	F1S1=2
Equipment/Machinery Failure (Engine Room)	**F3S2=5**	**F4S2=6**	**F3S2=5**	**F4S2=6**	**F1S1=2**
Weather Effects	F3S1=4	F4S1=5	F2S1=3	F3S1=4	F4S1=5

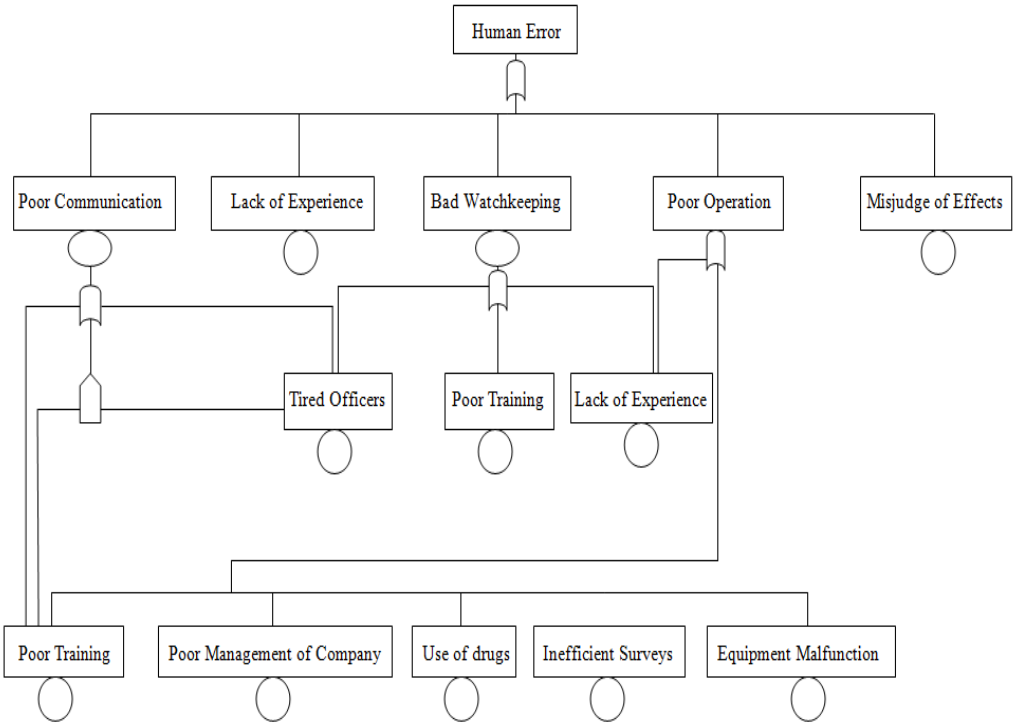

Fig. 6. FTA of human error for collision/contact/allision category

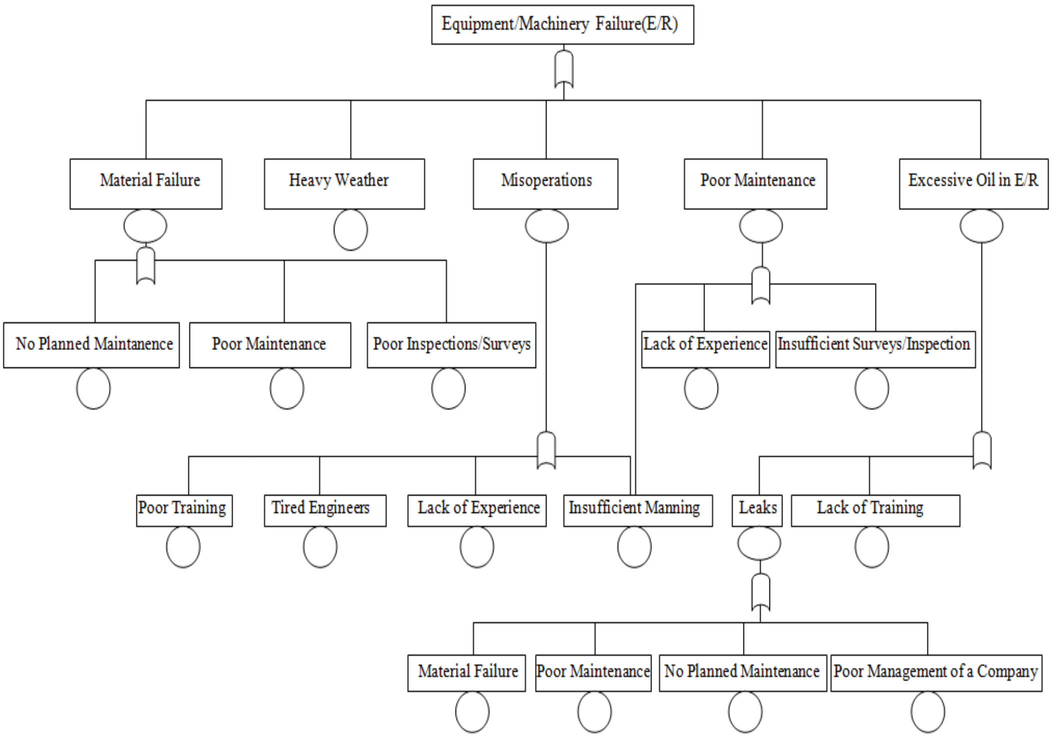

Fig. 7. FTA of equipment/machinery failure in engine room for fire/explosion category.

Now here is proceeding next step, which means step 3 aims to create risk control options to identify the risk areas. With this step, both existing and new risks can be examined and at the end, wide range of risk control options are to be considered. The purpose of this step is to obtain effective and practical measures to control and as well as reduce the risks. Please see Fig. 8 in order to understand the chain for the process of step 3.

This step can be comprised by 4 stages. The first one is focusing on risk areas needing control, second one is identifying potential risk control measures (RCO), third one is evaluation the effectiveness of the RCO in reducing risk by re-evaluating step 2 and last one is grouping RCOs into practical regulatory options [1]. At this point, as mentioned above Fault Tree Analysis has been used in order to define "Cause", "Incident" and "Accident". Consequences may vary however as it has been mentioned before, on this paper the focus points are Collision/Contact/Allision and Fire/Explosion. It is safe to assume our consequences are in line with these hazards. Our aim is to understand as follows:

1. Intervention to remove cause.
2. Intervention before the incident.
3. Intervention before the accident.
4. Intervention before the consequence.

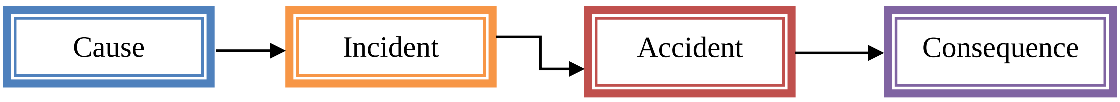

Fig. 8 Chain of events

As this paper divided into two main hazards, now it shall be followed as same manner, firstly, collision/contact/allision category due to human error will be investigated and then the other one. For this matter, in order to understand RCO chain of event, please see Table 4 for Human Error and see Table 5 for Equipment/Machinery Failure(E/R) for both sub-categories.

Table 4. Risk control options for collision/contact/allision category

<table>
<tr><th>Possible Causes</th><th>Possible Incident</th><th>Possible Accident</th><th>Possible Consequence</th></tr>
<tr><td>Poor Training</td><td>Poor Operation</td><td rowspan="3">Collision</td><td>Damage to ship</td></tr>
<tr><td rowspan="2">Poor Management of a Company</td><td rowspan="2">Poor Communication</td><td>Sinking</td></tr>
<tr><td>Loss of Cargo</td></tr>
<tr><td>Use of Drugs</td><td rowspan="3">Lack of Experience</td><td rowspan="3">Contact</td><td rowspan="2">Loss of life</td></tr>
<tr><td rowspan="2">Inefficient Surveys</td></tr>
<tr><td>Fire/Explosion</td></tr>
<tr><td rowspan="2">Equipment Malfunction</td><td>Misjudge of Effects</td><td rowspan="2">Cargo Shift</td><td>Missing Voyage</td></tr>
<tr><td rowspan="3">Maneuvering Faults</td><td>Damage to Equipment</td></tr>
<tr><td>Tired Officers</td><td>Allision</td><td rowspan="3">Damage to environment/Surroundings</td></tr>
<tr><td rowspan="2">Heavy Weather</td><td>Drifting</td></tr>
<tr><td rowspan="2">Bad Watchkeeping</td><td rowspan="2">Loss of Navigation</td></tr>
<tr><td>Lack of Experience</td><td>Collision/Contact</td></tr>
</table>

Table 5. Risk control options for fire/explosion category

<table>
<tr><th>Possible Causes</th><th>Possible Incident</th><th>Possible Accident</th><th>Possible Consequence</th></tr>
<tr><td>Material Failure</td><td>Leaks</td><td rowspan="2">Fire</td><td>Sinking</td></tr>
<tr><td rowspan="2">Poor Maintenance</td><td rowspan="2">Excessive oil in E/R</td><td rowspan="2">Damage to Equipment</td></tr>
<tr><td rowspan="2">Explosion</td></tr>
<tr><td rowspan="2">No Planned Maintenance</td><td rowspan="4">Material Failure</td><td rowspan="4">Damage to Ship</td></tr>
<tr><td rowspan="2">Leaks</td></tr>
<tr><td rowspan="2">Poor Management of a Company</td></tr>
<tr><td rowspan="3">Sparks</td></tr>
<tr><td>Lack of Training</td><td>Poor Training</td><td>Loss of Life</td></tr>
<tr><td rowspan="2">Insufficient Surveys/Inspections</td><td rowspan="4">Overheating of equipment</td><td rowspan="3">Loss of Voyage</td></tr>
<tr><td rowspan="4">Flame</td></tr>
<tr><td>Lack of Experience</td></tr>
<tr><td rowspan="3">Tired Engineers</td><td rowspan="3">Missing Next Voyage</td></tr>
<tr><td rowspan="2">Sparks</td></tr>
<tr><td rowspan="2">Overheating of equipment</td></tr>
<tr><td>Leaks</td><td rowspan="5">Misoperation</td><td rowspan="3">Damage to Environment</td></tr>
<tr><td>Insufficient Manning</td><td rowspan="4">Equipment/Machinery Failure</td></tr>
<tr><td rowspan="2">Poor Surveys/Inspections</td></tr>
<tr><td rowspan="2">Fire/Explosion</td></tr>
<tr><td>Heavy Weather</td></tr>
</table>

After the analyzing all these tables and FTA, interventions can be assumed in order to reduce risks and decide cost/benefits accordingly. In this paper, collision/contact/alision due to human error and fire/explosion due to equipment/machinery failure in engine room have been chosen therefore, our interventions will be in this order.

These interventions may be as follows for collision/contact/allision:
1. Intervention to remove cause;
- Improve training,
- Improve management through company,
- Prohibition of drugs, alcohol (including fine),
- Improving efficiency of surveys,
- Planned maintenance implementation,
- Improvement on manning (Better agencies, better HR departments etc.),
- Using proper and new equipment

2. Intervention to remove incident;
- Proper communication,
- Trained/experienced officers,
- Better implementation of company regulations (such as ISM, internal regulations etc.)
- Equipment specific training by 3rd companies.

3. Intervention to remove accident;
- Operational specific training,
- Proper watchkeeping,
- Proper loading of cargo

4. Intervention to remove consequence;
- Notification to officers/master,
- Notification to port authorities,
- Fire fightning training,
- Emergency response drills,
- Emergency instructions

These interventions may be as follows for Fire/Explosion:
1. Intervention to remove cause;
- Proper Inspections and/or surveys,
- Implementation of planned maintenance,
- Implementation of better management through company,
- Proper training schedules,
- Improvement of manning through agencies, HR departments etc.,
- Improvement on resting hours (MLC 2006 Convention etc.)

2. Intervention to remove incident;
- Observing machinery,
- Patrol surveys/inspections,
- Proper cleaning in E/R,
- Proper watchkeeping for duty engineers,
- Proper storage of spare parts.

3. Intervention to remove accident;
- Additional fire extiungishers,
- Additional heat/smoke/flame detectors,
- Additional fire hoses,
- Fire fighting training,
- Additional fire drills,

- Proper communication,
- Proper repair

4. Intervention to remove consequence;
   - Emergency response drills,
   - Emergency instructions,
   - Notification to chief engineer/master,
   - Abandon ship training,
   - Additional fire fighting system (sprinkler etc.)
   - Notification to port authorities,
   - Implementation of ship specific emergency procedures.

Now, it is time to proceed step 4 cost benefit assessment. Hereby in Table 6, basic calculation for cost benefit assumption has been shared. This step aims to understand and also compare the benefits from reduced risks and cost of implementation of RCO as defined in step 3. Following tables have been created in order to calculate cost - benefit assessment. At first, benefit has been assumed based on expert opinion, historical data and maintained applications on-board. After this, a cost has been identified in order to create intervention. Followingly, overall score can be calculated. In Table 7 and Table 8 cost benefit analysis results have been published. It is needlessly to say that an orderly fashion is to be created to understand the best intervention in regard to cost/benefit assessment.

Table 6. Cost benefit description

Range	Estimation of benefit Description	÷	Estimation of Cost Description	= Overall Score
1	No benefit	÷	No cost for implementing Countermeasure	= Result
2	Low benefit	÷	Small cost	= Result
3	Medium benefit	÷	Medium cost	= Result
4	High benefit	÷	High cost	= Result
5	Very high benefit	÷	Very high cost	= Result

Table 7. Cost benefit analysis for collision/contact/allision category

Intervention To Remove Cause	**Benefit Assessment**	**Cost Estimation**	**Overall Score**
Improve training	4	2	2
Improve management through company	3	4	0.75
Prohibition of drugs, alcohol	5	3	1.67
Improving efficiency of surveys	5	4	1.25
Planned maintenance implementation	2	2	1
Improvement on manning	5	5	1
Using proper and new equipment	4	3	1.33
Intervention To Remove Incident	**Benefit Assessment**	**Cost Estimation**	**Overall Score**
Proper communication	5	2	2.5
Trained/experienced officers	5	5	1
Better implementation of company regulations	4	2	2
Equipment specific training by 3rd companies	3	2	1.5
Intervention To Remove Accident	**Benefit Assessment**	**Cost Estimation**	**Overall Score**
Operational specific training	4	2	2
Proper watchkeeping	4	1	4
Proper loading of cargo	3	1	3

Intervention To Remove Consequence	Benefit Assessment	Cost Estimation	Overall Score
Notification to officers/master	3	2	1.5
Notification to port authorities,	3	2	1.5
Fire fightning training	4	2	2
Emergency response drills	3	2	1.5
Emergency instructions	3	1	3

Table 8 . Cost benefit analysis for fire/explosion category

Intervention To Remove Cause	Benefit Assessment	Cost Estimation	Overall Score
Proper Inspections and/or surveys	5	4	1.25
Implementation of planned maintenance	4	2	2
Implementation of better management through company	3	3	1
Proper training schedules	3	2	1.5
Improvement of manning	5	5	1
Improvement on resting hours	2	1	2
Intervention To Remove Incident	**Benefit Assessment**	**Cost Estimation**	**Overall Score**
Observing machinery	5	2	2.5
Patrol surveys/inspections	5	3	1.67
Proper cleaning in E/R	3	2	1.5
Proper watchkeeping for duty engineers	4	2	2
Proper storage of spare parts	1	1	1
Intervention To Remove Accident	**Benefit Assessment**	**Cost Estimation**	**Overall Score**
Additional fire extiungishers	4	2	2
Additional heat/smoke/flame detectors	4	3	1.33
Additional fire hoses	3	2	1.5
Fire fighting training	4	2	2
Additional Fire drills	3	2	1.5
Proper communication	4	2	2
Proper repair	5	3	1.67
Intervention To Remove Consequence	**Benefit Assessment**	**Cost Estimation**	**Overall Score**
Emergency response drills	3	2	1.5
Emergency instructions	3	1	3
Notification to chief engineer/master	4	2	2
Abandon ship training	4	2	2
Notification to port authorities	3	2	1.5
Implementation of ship specific emergency procedures	3	1	3

When the cost/benefit assessment has been checked for collision/contact/allision, it can be clearly seen that there are some intervention items having better overall score than others. Among all interventions, improving training is the most effective way. Especially, when a ship specific training could be implemented before attending on board or joining crew, would be very helpful. And these kind of training also can be given by responsible persons in the company and thus, costs can be reduced in the long term. Even though 3rd companies are arranged, still shore training would be very helpfull and less costly.

To remove incident, it is clearly can be seend tht the proper communication is the most effective. It doesn't come with a great cost and implementing additional lines and/or communication chain of command will be very effective. When the incidents checked, with proper communiction most of them cn be eliminated. For example, even the engineer and/or officer is less experiences, with proper communication chief engineer and/or captain can supervise that crew. In the same sense, many things can be eliminated with this way. To remove accidents, proper watchkeeping is a lot more effective than the others. According with the historical data, many accidents have occured due to poor watchkeeping. It is not costly and with the proper guidance, watchkeeping can be improved great deal. To remove consequence, emergency instructions and fire fighting training seem better picks. Even though arranging training can cause to spend some money, it can be effective for the ship crew to react fires on board. Emergency instructions will be very helpful too, these procedures can be created with a very little cost, however, can be implemented through ISM implenentations of a ship.

When the fire/explosion checked, on the first intervention, planned maintenence and improving resting hours can be picked. Even though improving manning (through agencies and/or better HR departments), can add great benefit. However, the cost will be greater too. The most beneficial solution is planned maintenance implementation on board to material failure. Ships already must have relevant spare parts and with the planned maintenance, in the long term, it will help company to reduce costs by preventing and damage to equipments before happened due to planned maintenance. At the second intervention, observing machinery seems the best solution. An oberservtion can be made by duty engineers and aslo can be recorded for the further information. This doesnt affect the general cost but this can improve the monitoring of risky equipmentes before any failure or malfunction.

When the intervention to remove accident is checked, there are several options with the higher score than others. Proper communication and additional fire extiungishers could be picked to remove any fire or flme or sparks. With proper communication, many problems and observations can be solved beforehand especially with the supervision of higher rank crew. Also, additional fire extiungishers can be effective to deal any kind of fires/sparks before getting dangerous and bigger. Therefore, additional extinguishers cn be put on board even though they are not mandotary to use highher numbers. In order to remove the last stage, emergency instructions and ship specific procedures can be very effective. In accordance with previous steps, to avoid such consequence, ship crew must be very good at ship handling and the reaction in that specific ship.

The last step helps to make a decision and giving a recommendation for safety. In other words, with proceeding step 5, recommendations are to be presented to keep risks minimum as much as possible. Output of this step should give an objective comparison of alternative options based on the potential reduction of risks and cost effectiveness in areas where legislation or rules should be reviewed or developed and feedback information to review the results generated in previous steps [1]. At this point, the recommendations are to be divided into two groups for "Collision/Contact/Allision" category and for "Fire/Explosion" category.

In this paper, human error has been assessed for the collision category. When the historical datas have been checked, it is very clear that the human factor is the most contributing effect to the this type of hazard and therefore, it has chosen. In this regard, human error is a good choice. It can be seen that the operational mistakes and less experience are the most important factors. Especially, crew related this sub category must be focused through the interventions and implementations of improvement of crew. Better training schedules and implementation will have great impact. Also, related prohibitions, internal regulations and such through the management company will be effective too. While doing these, communication, watchkeeping and as well as judging effects by the crew will be increased positively. Of course, at the last stage, these improvements will be effective on emergency situations too such as fast response on hazardous situations, executions of drills etc.

Now for fire category, machinery failure in engine room has been chosen. Through the historical data, many fire accidents have been occured due to equipment/machinery malfunciton such as cracked fuel injection valve, overused equipment, overheating etc. In order to avoid these kind of problems, implementation of planned maintenance system is necessary. With this implementation, many problems and as well as failures could be solved beforehand. For example, heavily corroded piece can be cracked or leak in time. Of course it will be very easy to solve this with planned maintanence system onboard. Also, observing machinery will be very effective too. With a little cost, duty engineers can carry our patrol surveys in engine room to observe machinery for any malfunction or misoperation. At latter stages, of course additional extinguishers are very helpful to avoid big fires and flames.

4. Conclusion

With this study, OSVs or Offshore Support Vessels have been examined with FSA method. "Collision/Contact/Allision" category and "Fire/Explosion" category have been chosen due to accidents in the past and experts judgements. Especially after checking the historical data as well as reference [11], these categories chosen specifically.

Human error is the most contributing factor especially for collision category. Misoperation, misjudge of effects, poor communication and poor trained crew can lead very big accidents and collisions with other ships. As mentioned above, there are many cases, collision and contact occured due to poor communication between ships. For example, in one accident in 2013, ship captain's misjudgment of effects caused the allision. Therefore, it was important to focus on this effect and it will be beneficial for ship operators to conduct preventive measures. For this matter, when the results have been checked, the common causes are lack of training, equipment malfunction and relatively poor judgement. There is a big responsibility for management companies/owners to provide adequeate training for ship crew as well as intensification of inspections in order to avoid malfunction of equipment due to human error. For example, companies may apply strict applications of drills, equipment trainings and sufficient supervision. In Turkey, there are several management companes apply these such kind of supervision to their ships which greatly reduced human error considering past occurences.

For fire category, machinery failure in engine room is focused on due to frequent occurence and expert opinions from recognized organizations. It is very clear that the planned maintanence and obervation of machinery are very effective ways to prevent any kind of flame, overheating or fire. These are can be considered also preventive measures for this category. It is sad to report that and understandably considering not mandotary application many compaines avoid planned maintenance scheme. However, a good application of planned maintenance with the support of software can greatly reduce the risk of overheating, malfunction and such. Also, again in relation with the above, properly trained ship crew can observe machinery more efficiently and able to be understand the problems before accidents. Therefore again, compaines shall apply more strict training and/or supervision procedures. Some companies carry out such kind of trainings however, it is not very common application.

Using the suitable FSA methodology, OSV crew, their operators and related personnelle can find accepable ways to improve safety while considering the cost of these improvements. This analysis of course does not cover the whole analysis of OSVs, however, it gives a practical way of understanding by means of safety with focusing on most risky categories. With this study, ship owners or management companies are able to be grasp the basic idea of safety in relation to most risky categories and can adjust their internal procedures accordingly.

On the other hand, this FSA method application has been based on expert judgements and historical data without any mathematical and/or statistical methods. Especially considering the human effect, it might be inevitable to include mathematical and/or statistical approaches in the future work. When the human contribution is only based on expert judgement/historical data, making the systematical work to apply generally will lack. This applies in the same sense for material failures, weather effect judgements etc. Therefore, a future work for this sense should be adopted.

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