Current Journal of Applied Science and Technology

Volume 41, Issue 42, Page 32-44, 2022; Article no.CJAST.93836
ISSN: 2457-1024
(Past name: British Journal of Applied Science & Technology, Past ISSN: 2231-0843, NLM ID: 101664541)

Quantitative Risk Assessment of Naval Vessels Operating in Niger Delta Waterways Using Fault Tree Analysis

Ido J. Akpan [a], Ify L. Nwaogazie [b*] and Patricks Chinemerem [a]

[a] Centre for Occupational Health, Safety and Environment, University of Port Harcourt, Rivers State, Nigeria.
[b] Department of Civil & Environmental Engineering, University of Port Harcourt, Rivers State, Nigeria.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/CJAST/2022/v41i424000

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/93836

Original Research Article

Received: 16/09/2022
Accepted: 20/11/2022
Published: 30/11/2022

ABSTRACT

This study investigated the quantitative risk assessment of the naval ships operating within Niger-Delta, Nigeria. Descriptive and analytical research designs were adopted. Three accidents prevalent in naval ships and the associated hazards that caused these accidents were identified using the Nigerian Navy safety ledger (2010-2019). The accidents are Slip and fall accidents, Electrical accidents and Mooring operation accidents. The risk assessment was conducted by ranking of the hazards based on their risk rating using Conventional Risk Assessment (CRA) which involved multiplying the likelihood of the hazards to cause harm and the severity of the harm when it occurs. The severity and likelihood of the hazards were obtained using questionnaire and the respondents were forty-four (44) principal officers in the Eleven (11) naval ships. The results obtained were used to carry out Fault Tree Analysis (FTA) and the final outcome of the FTA revealed that the three main causes of these three accidents were poor management, lack of safety awareness and consciousness and violation of rules of safety on-board. It was then

**Corresponding author: E-mail: ifynwaogazie@yahoo.com;*

recommended, among others, that safety managers on-board naval ships should organize safety workshops for naval personnel to improve their safety awareness. Given that all the prevailing accidents, naval ships and major naval officers were not involved in this study is the major limitation of this study. It is recommended that more studies be carried out using other risk assessment tool like the Fuzzy Analytic Hierarchy Process (AHP).

Keywords: Quantitative; risk assessment; naval vessels; Niger Delta; fault tree analysis.

1. INTRODUCTION

Over 90% of the world's international and local travels and trading are by sea, therefore Seafaring plays a major part to the world's economy in areas of global economic development, tourism as well as inter-dependency among nations which largely rely on the success of the maritime industry [1]. Unlike other means of transportation, maritime or sea-based transportation, with the help of the navy, has proved to be the most cost-effective way of conveying bulk goods, petroleum products, food supplies, manufactured goods, containerized cargo, etc., over long distances [1]. The ship, as the workplace, has the potential of immediate cause of harm to a naval officer which are generally called occupational hazards and include ship collision, struck-by/caught-in /caught between, explosion/fires, ergonomic hazards, high pressure equipment, electrical and other hazardous energy, falls, confined spaces machine hazards etc [2].

Seafaring is a high-risk occupation, and the safety aspect of work on board ships is the main concern for seamen and the naval officers all over the world. The increased rate of mortality due to occupational hazards at sea has been reported to be responsible for the high incidence of occupational accidents among other workers. Also, it has been linked that these accidents were due to poor knowledge of hazards and safety practices among seamen falling into docks when boarding the ships from ashore [3]. It has been also estimated globally that there are more than 350,000 workplace fatalities and over 270 million workplace injuries annually caused by occupational hazards [4]. According to previous studies, occupational hazards have caused loss of 3.5 years of healthy life for every 1,000 workers, [5]. Hence, about 300,000 of the occupational injuries among workers were caused by occupational hazards present in the working environment [6].

In Africa, there is no detailed work published on the risk assessment of naval vessels operating in Niger Delta waterways. However, in Nigeria, based on experience as a naval officer, risk assessment of naval ships operating in Niger-Delta is based on managerial objective of identifying and mitigating accidents based on the conventional Health, Safety and environment (HSE) rules without a standardized occupational health and safety risk management framework. Thus, in Nigerian naval units, occupational health and safety is also a serious concern because of problem that is applicable to European-based naval units such as complex arrangements and networks of mechanical and electrical systems, high explosive artillery storages, battle stations and living areas being confined in limited space as well as the fact that most Nigerian naval units and ships are old and out-dated. This equally necessitates special attention to risk assessment of naval ships operating within Niger-Delta, Nigeria. Thus this study is aimed at quantitatively assessing the risk level of some hazards associated with some accidents in naval ships operating in Niger-Delta, Nigeria and the objectives are; one, to identify some accidents that occur on-board Nigerian Navy Ships operating in Niger Delta, Nigeria; to determine the various hazards associated with these accidents identified on-board Nigerian Navy ships operating in Niger Delta, Nigeria; analyse the risk level of the hazard effects using their severity and probability of occurrence of these accidents identified above and develop a risk assessment model using outcome of the risk levels based on Fault Tree Analysis (FTA).

FTA is one of the most popular Quantitative Risk Assessment (QRA) methods that can be used in both probabilistic and possibility uncertain conditions. Probabilistic FTA is applicable when enough historical data about Basic Event exist. In majority of cases, owing to different reasons such as imprecise historical data, using probabilistic FTA is not possible. In this situation, possibility FTA can be utilized to deal with these types of uncertainties. However, any engineering system has different types of uncertainties in its input variables. In real world situation, some uncertain variables are objective and some are subjective. In this situation, neither pure probabilistic nor pure possibility FTAs can be used alone but a new hybrid method is required. This section thoroughly investigates previous studies that used FTA in both uncertain spaces and highlights limitations of those studies in which joint propagation of objective and subjective uncertainties is proposed.

In some of the previous studies done using FTA, historical data has been utilized for quantifying uncertainties. Chang et al. [7] in their empirical work titled "Failure Mode and Effects Analysis Using a Group-based Evidential Reasoning Approach" in which they applied FTA to analyse the failure of the soil nailing system and cement–soil retaining wall. They used the historical data of 342 actual excavation accidents in China to obtain frequency distributions of different accident causes and estimating the value of the Top Event.

Ten veldhuis et al. [8] in another work titled "Quantitative Fault Tree Analysis for Urban Water Infrastructure Flooding" in which they applied probabilistic FTA to evaluate the probability of urban water infrastructure flooding as a result of a range of causes. Similarly, Moinuddin and Thomas [9] also used FTA to estimate the overall reliability of sprinkler systems in high-rise office buildings in Australia by using data from 26 projects in their work titled, "Reliability of Sprinkler System in Australian High Rise Office Buildings."

Ardeshir et al. [10] in their study titled “Risk Assessment of Construction Projects for Water Conveyance Tunnels Using Fuzzy Fault Tree Analysis” combined two major risk assessment models namely FTA and Analytic Hierarchy Process (AHP), along with a fuzzy sets analysis to account for the uncertainties and vagueness of real life data during the risk assessment study. FTA was utilized to identify and present the major causes of events and incidents. Fuzzy sets were incorporated with the FTA to calculate the possibility of incidence and the severity of the risk while AHP was then applied to estimate the significance of time, cost, quality and safety factors. This model framework was tested using a case study in a water conveyance tunnel and the result revealed that the model is effective and robust especially in risk assessment of complex and real life systems. However, and just like the other AHP based model presented, they failed to utilize several other risk element and they also used only one Multi-Criteria Decision-Making (MCDM) method without comparing the result with results of other MCDM techniques. These empirical reviews revealed that, so far, no empirical studies have been done to quantitatively conduct risk assessment on Nigerian naval ships operating within Niger-Delta. Thus, this study is designed to fill this gap.

2. METHODOLOGY

2.1 Study Design

The nature of this study requires a combination of descriptive and analytical research designs. Descriptive design will be used during the identification of major accidents and their associated hazards in the naval ships operating within the Niger Delta which covers objectives one and objective two of this study while the analytical design will be used to develop risk assessment of the hazards, development of the model’s using FTA.

2.2 The Study Population

The population of this study covers the naval officers who are heading the Nigerian Naval ships located within the Niger Delta waterways. The operational naval bases in the Niger Delta are grouped into two; the major or bigger bases are usually designated as the Nigerian Navy Ships (NNS) and the smaller bases designated as the Forward Operating Bases (FOB). Eleven ships were used for this study. These NNSs are berthed along the jetty of the Nigerian Port Authority (NPA) Onne and have at least 1 Commander, 1 Executive Officer, 1 Marine Engineering Officer and 1 Weapon Engineering Officer. These are the 4 high ranked officers on-board each of the naval ships and they are the safety experts on-board because they take charge of safety on-board the ships. They are assigned the markings EX1, EX2, EX3 and EX4 respectively thus making it at least 4 high ranked officers per ship and a total of 44 officers. Thus, the study population is 44.

2.3 Sampling Technique

A purposive sampling technique, also known as judgemental sampling technique, was used in this study because the sample size is small and limited (11 ships) and the judgement of the researcher is crucial in selecting the number and type of ships needed in this research. Thus, the entire 11 ships mentioned earlier were selected making the sample size of the study 44 respondents. This sampling technique is considered adequate because it covered all members of the study population (44) respondents. However, the respondents in this study are the major key players who are directly or indirectly concerned with the safety of the naval personnel on board and operations of the ships.

2.4 Nature and Source of Data

Both primary and secondary data were used in this study. The secondary data were the documented accidents and near-misses' data from the sampled ships while the primary data will be response of the officers that were obtained using well-structured questionnaire that will be distributed to the sampled officers in the ships. The accidents and near-misses' data (secondary data) were used to identify the three major accidents encountered by these ships and their corresponding hazards which are occupational health related while the questionnaire will be used to ascertain the information on for risk assessment specifically the likelihood, severity and frequency of the hazards, and the risk assessment will be needed for Fault Tree Analysis (FTA).

2.5 Methods of Data Collection

Data was collected based on the time of the availability of the officers sampled. The purpose of the study was explained to these eligible participants. The study questionnaires were distributed to them on the days of data collection. The questionnaires were self-administered. All duly completed questionnaires were retrieved on the spot and cross-checked for completeness. Due to size and type of the sampled respondent as well as the sensitivity of the research, only the researcher administered the questionnaire, or possibly accompanied by 1 research assistant.

2.6 Instrument for Data Collection

A closed ended and modified 5-point Likert scaled questionnaire was used in this study because this study requires a specific answer to questions that was designed to elicit information from the respondents on scaled questions designed to obtain the degree or level of the respondents feeling toward a quantified subject's answers. Thus, the respondents were not given the room to freely express their opinion on the subjects of the questions rather they were only allowed to present their opinion based on degree or level of their experiences and information towards the subject of the questions as was presented to them by the researcher. See Tables 1 and 2 below. The Questionnaire was comprised of Six (6) sections: A to F. In terms of their risk level, a Risk Assessment Matrix (RAM) designed by National Patient Safety Agency 2008 (NPSA, 2008) was used to assess the risk level of the hazards.

Section A: Obtain responses on socio-demographic characteristics of the respondents.

Section B, C, D, E and F: Used to obtain responses on the risk assessment of the hazards associated with the three accidents selected, probability of occurrence of these accidents and the chances of their various causes identified. Note, there will be three sub-sections for each of the main sectioned labelled 1, 2, 3 and each subsection will be used to elicit data on likelihood and severity of the hazards associated with the selected accidents. The three accidents identified were: 1, slips/fall 2, mooring operation accidents 3, electrical accidents.

Table 1. Assessment of likelihood of the hazard to cause accident

Linguistic terms	Scale value
Rare	1
Unlikely	2
Possible	3
Likely	4
Almost Certain	5

(Source; NPSA, 2008)

Table 2. Assessment of severity of accident caused by the hazard

Linguistic terms	Scale value
Negligible	1
Minor	2
Moderate	3
Major	4
Catastrophic	5

(Source; NPSA, 2008)

2.7 Methods of Data Analysis

The data were analysed in four different stages, which were designated at Stage One, Stage Two, Stage Three and Stage Four.

Stage One: This stage involved using the accident and near-misses' data to identify the major and commonest accidents in the sampled ships based on their frequency of occurrence. This stage also involved checking and identifying the possible hazards responsible for these accidents.

Stage Two: The data obtained from the respondents on the likelihood and severity of the hazard effects for each of the three accidents were used to develop Risk Assessment Matrix (RAM) so that the risk will be ranked.

Stage Three: The Risk Assessment Matrix and the corresponding hazard effects ranking results were used to design the FTA model.

Stage Four: This stage involved carrying out analysis on the results of the FTA model obtained from the FTA modelling procedure.

The results of the Risk Assessment of the naval ship are presented thus; the risk assessment was started by identifying the three major accident cases prevalent in naval ships based on recorded statistics of the accident in the naval ship within the Niger-Delta. The three most prevalent accidents which are accidents with the highest number of occurrences are seen in Table 3 below and were selected for the risk assessment.

From Table 3, the three most prevalent accidents are those with the highest number of occurrence and they include; Slip and fall accidents, Electrical accidents and Mooring operation accidents. The various hazards or causes of these accidents were also identified using the naval safety ledger.

The risk assessment was conducted using the ranking of the hazards based on the position in the Risk Assessment Matrix, and to design the Risk Assessment Matrix (RAM) we carry out risk assessment to ascertain the risk score or level of the hazard based on determination of product of the severity of the hazard and their likelihood of occurrence, given as:

1. S (severity) × L (likelihood) = R (risk rating or level)

To determine the severity and likelihood of the hazards, questionnaire was designed and administered to the top-four high ranked officers in the naval ships as the study respondents.

The data obtained from the respondents on the severity and likelihoods of the hazard for each of the three accidents were used to ascertain the risk score and the results of the risk scores or level obtained are as thus. Conventional Risk Score = S (severity) × L (likelihood).

3. RESULTS

3.1 Result of Risk Assessment for Slip and Fall Accident

The hazards associated with slip and fall accidents are presented in Table 4.

The conventional risk score obtained based on responses from respondents on the hazards associated with slip and fall accident is given in Table 5. The arrangement on the hazard Table 5 is such that there are eleven (11) hazards being considered and they are represented with 1 to 11 respectively.

From Table 5, it was observed that the hazard with highest risk score is hazard number 11, which corresponds to poor visibility with risk score of 21.02 followed by hazard number 7 corresponding to slippery deck with risk score of 20.27, then followed by hazard number 1 which corresponds to excessive alcohol and hard-drug use with risk score of 19.98 while the hazard with least risk score is hazard 6 which corresponds to improper use of safety equipment.

Table 3. The most common accidents in naval ships

No.	Accident type	Number of accidents	Rank
1	**Slip and fall**	**8848**	**1ST**
2	Capsize/Listing	390	
3	Cargo Handling Failure	110	
4	**Mooring operation accident**	**1566**	**3rd**
5	Hazardous incidents	1310	
6	Escape of Harmful Substance	110	
7	Contact	593	
8	Foundering	524	
9	**Electrical accident**	**1802**	**2nd**
10	Pollution	50	

Source: (Naval Safety Ledger, 2010-2019)

Table 4. Hazards associated with slip and fall accidents

S/N	Hazards
1	Excessive alcohol and hard-drugs use
2	Working at height
3	Unsafe behaviour due to fatigue
4	Poor warning signage
5	Ship manoeuvre errors
6	Improper use of safety equipment
7	Slippery deck
8	Lack of safety awareness and consciousness
9	Violation of the rules of accident prevention in ship
10	Poor weather condition
11	Poor visibility

Source; (Naval Safety Ledger, 2010-2019)

Table 5. Conventional risk assessment (CRA) results for slip and fall accident

Hazards	Average risk score EX1	Average risk score EX2	Average risk score EX3	Average risk score EX4	Overall average risk score	Ranking
1	22.90	20.64	18.64	17.72	19.98	3^{RD}
2	15.90	17.09	17.27	16.55	16.70	6^{TH}
3	13.90	15.90	16.55	14.55	15.23	9^{TH}
4	19.73	18.64	16.72	15.27	17.59	4^{TH}
5	12.27	14.55	16.55	13.64	14.25	10^{TH}
6	11.64	12.74	15.27	13.55	13.30	11^{TH}
7	21.90	21.09	18.36	19.73	20.27	2^{ND}
8	14.90	19.64	16.82	17.18	17.14	5^{TH}
9	16.18	17.18	15.73	15.27	16.09	7^{TH}
10	14.90	13.64	15.55	11.55	13.90	8^{TH}
11	21.36	21.45	20.55	20.73	21.02	1^{ST}

Source; Researcher Computed Output

This means that from the responses of the respondents in which all respondents were assumed to be of equal safety experience and exposure, poor visibility was ranked as riskiest hazard to cause slip and fall accident followed by slippery deck and excessive alcohol and hard-drug use while improper use of safety equipment was considered the least risky hazard.

In terms of their risk level, a Risk Assessment Matrix designed by National Patient Safety Agency (2008) is used to assess the risk level of the hazards as seen in this Table 6. Note; in this Table 6, consequence is synonymous to severity while probability is synonymous to likelihood.

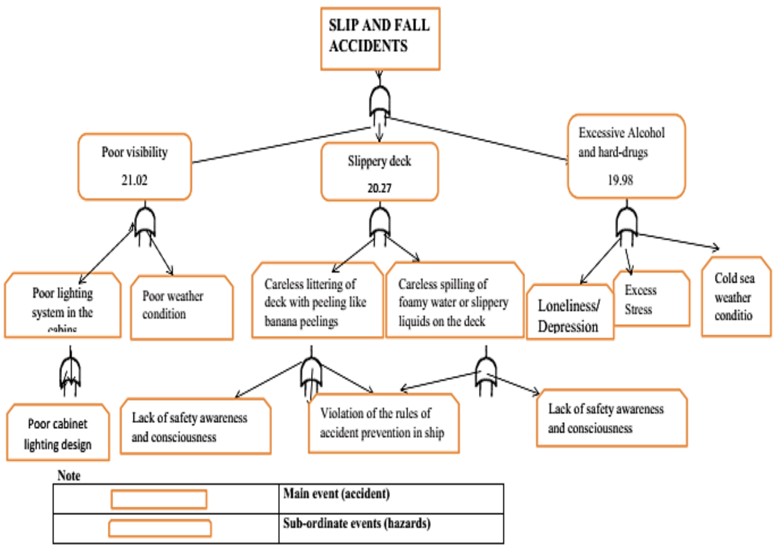

Fig. 1. Fault tree analysis for slip and fall accident

Table 6. Typical risk assessment matrix showing the various risk rating and colour bandings

	Likelihood				
Consequence	1	2	3	4	5
	Rare	Unlikely	Possible	Likely	Almost certain
5 Catastrophic	5	10	15	20	25
4 Major	4	8	12	16	20
3 Moderate	3	6	9	12	15
2 Minor	2	4	6	8	10
1 Negligible	1	2	3	4	5

Source: (National Patient Safety Agency, 2008)

For risk grading, the scores obtained from the risk matrix are assigned and graded as follows:

1–3	Low risk
4–6	Moderate risk
8–12	High risk
15–25	Extreme risk

Source: (National Patient Safety Agency, 2008)

Based on this Risk Assessment Matrix above and the Risk grading, it is obtained that hazard number 1,2,3,4,7,8,9 and 11 which correspond to "Excessive alcohol and hard-drug use, Working at height, Unsafe behaviour due to fatigue, Poor warning signage, Slippery deck, Lack of safety awareness and consciousness, Violation of the rules of accident prevention in ship, and Poor visibility respectively are extremely risky hazards while hazard number 5,6 and 10 which correspond to Ship manoeuvre errors, Improper use of safety equipment and Poor weather condition respectively are between extremely risky and high risky hazards.

Therefore, the most accurate risk ranking order for the hazards based on conventional risk score is given as:

> Hazard-11> hazard-7 > hazard-1 > hazard-4 > hazard-8 > hazard-2 > hazard-9 > hazard-3 > hazard-10 > hazard-5 and > hazard-6.

From this assessment, hazard 11, hazard 7 and hazard 1 are the three riskiest hazards responsible for slip and fall accident in naval ships within Niger-Delta Nigeria. Therefore, these three hazards were used to carry out the Fault Tree Analysis as showed in Fig. 1.

3.2 Risk Assessment of Electrical Accidents

The hazards associated with electrical accidents are presented in Table 7.

The conventional risk score obtained based on responses from respondents on the hazards associated with "Electrical Accident" is given in Table 8. The arrangement on the hazard table is such that there are twelve (12) hazards considered and they are represented with 1 to 12 respectively.

From Table 8, it was observed that the hazard with highest risk score is hazard 1 which corresponds to "Poor electrical connections" with risk score of 20.78 followed by hazard number 6 corresponding to "Poorly Insulated live Electrical-wires" with risk score of 20.67, then followed by hazard number 8 which corresponds to "Moisture on electric circuits" with risk score of 20.59 while the hazard with least risk score is hazard 10 which corresponds to "Violation of the rules of accident on-board".

This means that from the responses of the respondents whereby all respondents were assumed to have equal safety experiences and exposure, "Poor electrical connections" was ranked as riskiest hazard to cause electrical accident followed by "Poorly insulated live electrical-wires" and "Moisture on electric circuits" while "Violation of the rules of accident on-board" was considered the least risky hazard.

In terms of their risk level, a Risk Assessment Matrix (RAM) designed by National Patience Safety Agency (2008) was used to assess the risk level of the hazards as seen in Table 6 below. Note; in this Table 6 Consequence is synonymous to Severity while probability is synonymous to likelihood.

Based on this Risk Assessment Matrix and the risk grading, it is obtained that hazard number 1,3,4,5 6 8, 9 and 11 which correspond to "Poor electrical connections, Poor warning signage, Exposure to unsafe electrical surface, Lack of personal protection equipment, Poorly Insulated live Electrical-wires, Moisture on electric circuits, Lack of safety awareness and consciousness and Improper use of safety equipment respectively are Extremely Risky hazards while hazard number 7 and 12 which correspond to "Working at confine space and Excessive alcohol and drug use respectively are between Extremely risky and High Risky hazard." For hazard 2 and 10 which correspond to "Unsafe behaviour due to fatigue and Violation of the rules of accident on-board" respectively are High Risky hazards. Therefore, the risk ranking order for the hazards based on conventional risk score is given as:

> Hazard-1 > hazard-6 > hazard-8 > hazard-4 > hazard-9 > hazard-11 > hazard-3 > hazard- 5 > hazard-12 > hazard-7 > hazard-2 > hazard-10.

From this assessment, hazard 1, hazard 6 and hazard 8 are the three riskiest hazards responsible for electrical accidents in naval ships within Niger-Delta Nigeria. Therefore, these three hazards were used to carry out Fault Tree Analysis (FTA) as seen in Fig. 2.

Table 7. Hazards associated with electrical accidents

S/N	Hazards
1	Poor electrical connections
2	Unsafe behaviour due to fatigue
3	Poor warning signage
4	Exposure to unsafe electrical surface
5	Lack of personal protection equipment
6	Poorly Insulated live Electrical-wires
7	Working at confine space
8	Moisture on electric circuits
9	Lack of safety awareness and consciousness
10	Violation of the rules of accident on-board
11	Improper use of safety equipment
12	Excessive alcohol and drug use

Source; (Naval Safety Ledger, 2010-2019)

Table 8. Conventional risk assessment results for "Electrical Accidents"

Hazards	Average risk score EX1	Average risk Score EX2	Average risk score EX3	Average risk score EX4	Overall average risk score	Ranking
1	21.36	20.04	21.00	20.72	20.78	1st
2	9.55	11.09	10.27	13.55	11,12	11th
3	17.91	15.90	18.55	15.55	16.98	7th
4	21.00	19.64	20.72	20.27	20.41	4th
5	16.34	14.55	16.55	13.64	15.27	8th
6	21.32	20.74	19.27	20.55	20.67	2nd
7	11.32	13.09	1536	12.73	13.13	10th
8	20.72	19.64	20.82	21.18	20.59	3rd
9	19.34	17.18	18.73	19.27	18.63	5th
10	8.96	9.64	11.55	9.55	9.93	12th
11	16.36	17.45	15.55	18.73	17.52	6th
12	13.65	11.09	14.67	15.97	13.85	9th

Source; Researcher Computed Output

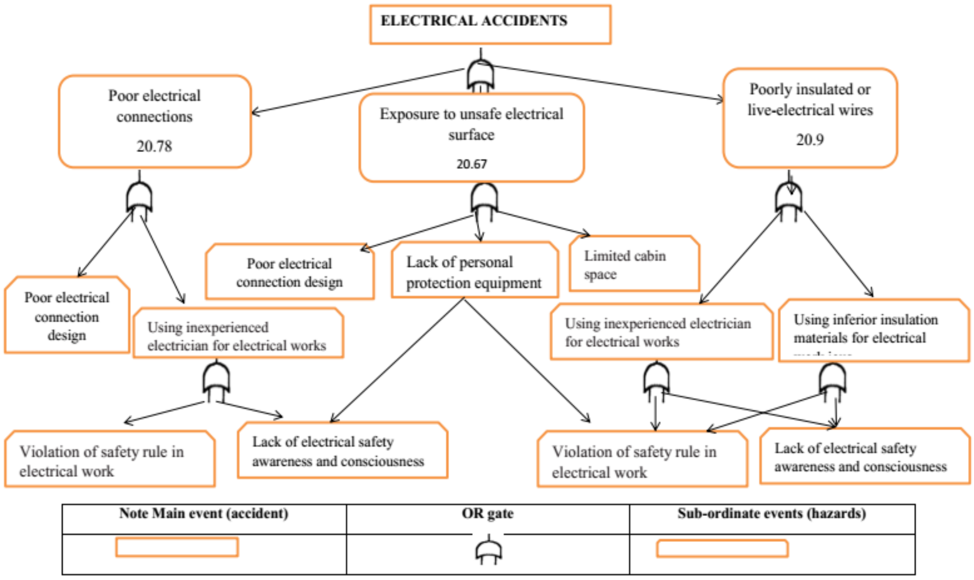

Fig. 2. Fault tree analysis for electrical accident

3.3 Risk Assessment for Mooring Operation Accidents

The hazards associated with “Mooring Operation Accidents” are presented in Table 9.

The conventional risk score obtained based on responses from respondents on the hazard associated with “Mooring Operation Accidents” is given in Table 10. The arrangement on the hazard table is such that there are ten (10) hazards considered and they are represented with 1 to 10 respectively.

Table 9. Hazards associated with “Mooring Operation Accidents”

S/N	Hazards
1	Improper positioning and posture while working
2	Unsafe behaviour due to fatigue
3	Poor warning signage
4	Excessive alcohol and drug use
5	Improper use of safety equipment
6	Lack of personal protective equipment
7	Lack of safety awareness and consciousness
8	Violation of rules of accident preventions
9	Unsafe handling of equipment and machines
10	Poor work schedule

Source; (Naval Safety Ledger, 2010-2019)

Table 10. Conventional risk assessment results for “Mooring Operation Accidents”

Hazards	Average risk score EX1	Average risk score EX2	Average risk score EX3	Average risk score EX4	Overall average risk score	Ranking
1	10.12	12.32	13.65	14.67	12.69	10^{st}
2	16.32	15.29	17.27	15.55	16.11	8^{th}
3	14.18	15.90	14.58	15.07	14.93	9^{th}
4	17.67	17.64	19.72	18.27	18.33	6^{th}
5	20.23	21.55	19.55	21.04	20.59	2^{ND}
6	19.67	20.74	19.34	20.67	20.11	3^{RD}
7	17.45	18.07	19.36	18.63	18.38	5^{th}
8	18.34	19.64	19.82	19.18	19.25	4^{TH}
9	21.00	20.18	21.73	20.67	20.90	1^{ST}
10	16.23	17.04	16.55	17.55	16.84	7^{TH}

Source; Researcher Computed Output

From Table 10, it was observed that the hazard with highest risk score was hazard 9 which corresponds to "Unsafe handling of equipment and machines" with risk score of 20.90 followed by hazard 5 corresponding to "Improper use of safety equipment" with risk score of 20.59, then followed by hazard 6 which corresponds to "Lack of personal protective equipment" with risk score of 20.11 while the hazard with least risk score is hazard 1 which corresponds to "Improper positioning and posture while working" with risk score of 12.69.

This means that from the responses of the respondents whereby all respondents were assumed to have equal safety experiences and exposures, "Unsafe handling of equipment and machines" were ranked as riskiest hazard to cause mooring operation accidents followed by "Improper use of safety equipment" and "Lack of personal protective equipment" respectively while "Improper positioning and posture while working" were considered the least risky hazard.

In terms of their risk level, a Risk Assessment Matrix (RAM) designed by National Patience Safety Agency (2008) was used to assess the risk level of the hazards as seen in Table 6. Note; in this Table 6, Consequence is synonymous to Severity while probability is synonymous to likelihood.

Based on this Risk Assessment Matrix and the risk grading in Table 6, it was obtained that hazard number 2, 4, 5, 6, 7, 8, 9 and 10 which correspond to "Unsafe behaviour due to fatigue, Excessive alcohol and drug use, Improper use of safety equipment, Lack of personal protection equipment, Lack of safety awareness and consciousness, Violation of rules of accident preventions, Unsafe handling of equipment and machines and Poor work schedule respectively were ranked as Extremely Risky hazards while risk assessment level for hazard 1 and hazard 3 which correspond to "Improper positioning and posture while working" and "Poor warning signage" respectively were ranked between Extremely risky and high risk hazard." Therefore, the risk ranking order for the hazard based is given as:

Hazard-9 > hazard-5 > hazard-6 > hazard-8 > hazard-7 > hazard-4 > hazard-10 > hazard- 2 > hazard-3 > hazard-1.

From this assessment hazard 9, hazard 5 and hazard 6 are the three riskiest hazards responsible for Mooring Operation Accidents in naval ships within Niger-Delta Nigeria. Therefore, these three hazards were used to carry-out Fault Tree Analysis (FTA) as showed in Fig. 3:

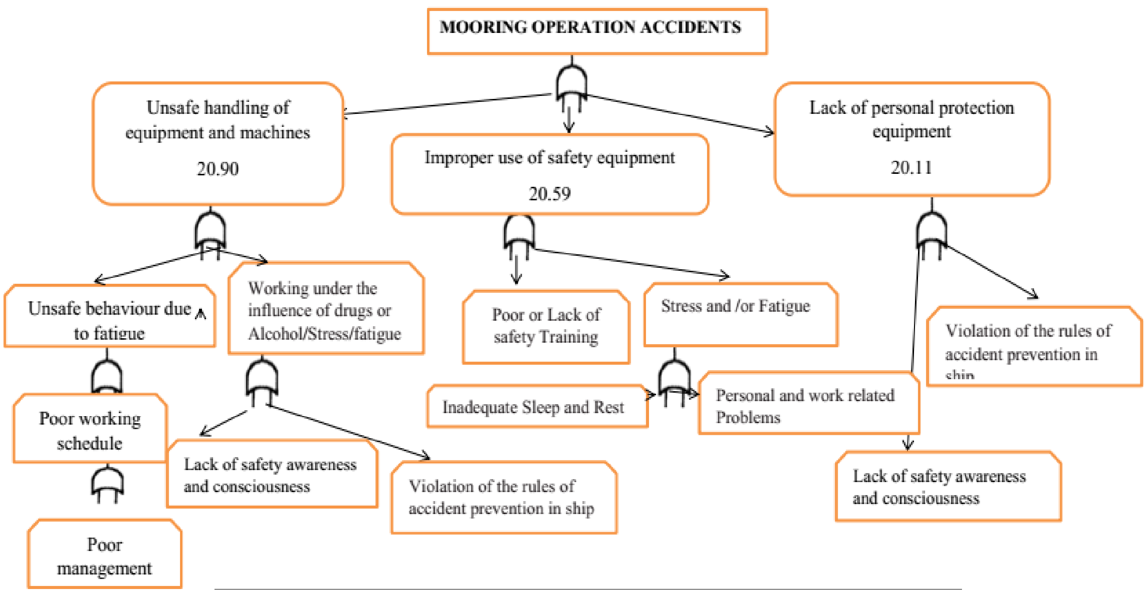

Fig. 3. Fault tree analysis for mooring operation accident

4. DISCUSSION

Based on the data obtained from the Nigerian Navy Safety Ledger, the three major accidents were identified based on their number of occurrences from year 2010 to year 2019, and the accidents identified were Slip and Fall Accident, Electrical Accidents and Mooring Operation Accidents. The hazards that were associated with these accidents were also sourced from Nigerian Navy Safety Ledger 2010-2019. Thus, risk assessments were conducted on these hazards using the responses obtained from the four principal officers in naval ships namely The Commander, The Executive Officer, The Marine Engineering Officer, and The Weapon Engineering Officer. The responses on Severity and Likelihood were obtained using Questionnaire. The risk assessment was conducted using Conventional Risk Assessment (CRA) and the results obtained are discussed as follow:

For the Slip and fall accident, there are eleven hazards associated to slip and fall accident and they are Excessive alcohol and hard-drug use, Working at height, Unsafe behaviour due to fatigue, Poor warning signage, Ship manoeuvre errors, Improper use of safety equipment, slippery deck, Lack of safety awareness and consciousness, Violation of the rules of accident prevention in ship, Poor weather condition and Poor visibility. The risk assessment carried out based on CRA revealed that the hazards with highest risk score were “Poor visibility” with risk score of 21.02 followed by “Slippery deck” with risk score of 20.27, and “Excessive alcohol and drug use” with risk score of 19.98 while “improper use of safety equipment” was the least risky hazard with risk score of 13.30. This means that from the responses of the respondents, whereby all respondents were assumed to have equal safety experiences and exposures, “Poor visibility” was ranked as riskiest hazard to cause slip and fall accident followed by “Slippery deck” and “Excessive use of alcohol and hard drug” while “Improper use of safety equipment” was considered the least risky hazard. Therefore, “Poor visibility, Excessive use of alcohol and hard drugs and Slippery Deck” which are the three riskiest hazards were used to design Fault Tree Model. It finally revealed that Poor management, Lack of safety awareness and consciousness and violation of safety rules were main or root cause of slip and fall accidents. This study aligned with the work of Ardeshir et al. [11] who applied FTA in order to identify the main causes of events and incidents in construction of water conveyance tunnels.

For Electrical Accidents, 12 hazards were identified and they are “Poor electrical connections, unsafe behaviour due to fatigue, Poor warning signage, Exposure to unsafe electrical surface, Lack of personal protective equipment, Poorly Insulated Live Electrical -wires, Working at confine space, Moisture on electric circuits, Lack of safety awareness and consciousness, Violation of the rules of accident on-board, Improper use of safety equipment and Excessive use of alcohol and hard drugs. The risk assessment conducted using CRA showed that “Poor electrical connection” with risk score of 20.78 was the riskiest hazard to trigger electrical accident in the naval ship, followed by “Poorly insulated or live electrical wire and moisture on electrical circuit” with risk scores of 20.67 and 20.59 respectively while “violation of rule of accident on-board” was the least risky hazard with score of 9.35. Therefore, the three riskiest hazards used to design FTA model were “Poor electrical connection, poorly insulated or live electrical wire and Exposure to unsafe electrical surface”. The model also points to the fact that “Poor management, Lack of safety awareness and consciousness and Violation of safety rules” are main causes of electrical accidents. This study also concurred with work of Moinuddin and Thomas [9] also used FTA to estimate the overall failure and sprinkler systems in high-rise office buildings in Australia by using data from 26 projects in their work titled, "Reliability of sprinkler system in Australian high rise office buildings".

For the Mooring Operation Accident, ten hazards obtained from Nigerian Navy Safety Ledger were used and the hazards included “Improper positioning and posture while working, Unsafe behaviour due to fatigue, Poor warning signage, Excessive alcohol and hard drug use, Improper use of safety equipment, Lack of personal protective equipment, Lack of safety awareness and consciousness, Violation of rules of accidents preventions, Unsafe handling of equipment and machines, and Poor work schedule.” The CRA analysis revealed that “Unsafe handling of equipment and machines” is the riskiest hazard with risk score of 20.90 followed by “Improper use of safety equipment” with risk score of 20.59 and “Lack of personal protective equipment” with risk score of 20.11 while “Improper positioning and posture while working” with risk score of 12.69 carried least risk. Thus, the three riskiest hazards in CRA were used to design the FTA model and these models also pointed the same facts that the root cause of Mooring Operation Accidents were Poor working schedule (poor managements), and Lack of safety awareness and consciousness and Violation of the rules of accident prevention in ship. This work also aligns with another work by Abdelgawad and Fayek [12] title "Fuzzy reliability analyser: quantitative assessment of risk events in the construction industry using fuzzy fault-tree analysis". Presented a comprehensive framework in which experts could apply numerals and subjective terms to evaluate the chances of occurrence failure based on FTA.

5. CONCLUSION

Based on the results of this study the three most prevailing accidents in the Nigerian naval ships operating within the Niger-Delta waterways, are slip and fall accident, electrical accidents and mooring operation accident. There are three major root causes of these accidents and they are poor management, lack of safety awareness and consciousness and violation of rules of safety on-board. “Poor electrical connection” with risk score of 20.78 was the riskiest hazard to trigger electrical accident in the naval ship, followed by “Poorly insulated or live electrical wire and moisture on electrical circuit” with risk scores of 20.67 and 20.59 respectively while “violation of rule of accident on-board” was the least risky hazard with score of 9.35.

Thus, management of the Nigeria naval ship should consider rearrangement of the management system in the ship, enforce complete compliance to safety rules and regulation and create more awareness on the danger of non-compliance to safety rules and regulation onboard the naval ship, as these are the main factors that would reduce the prevalence of the slip and fall accident, electrical accidents and mooring operation accidents in the ship, The fact that not all the prevailing accidents, naval ships and major naval officers were involved in this study is the major limitation of this study. It is recommended that more studies be carried out using other risk assessment tool like the Fuzzy Analytic Hierarchy Process (AHP).

CONSENT

As per international standard or university standard, Participants’ written consent has been collected and preserved by the author(s).

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Gino JL, Jaeyoung C, Selim B, Taofeek B, Hamid P. Models and computational algorithms for maritime risk analysis: A review. Annals of Operations Research, ANOR_11192017; 2019.
2. Patterson J. Occupational health hazards in manufacturing industries in Nigeria. Journal of Community Medicine and Primary Health Care. 2014;9(1997):26-34.
3. ILO. Accident Prevention on Board Ship at Sea and in Port, Geneva: International Labour Organization; 1996.
4. Barling J, Frone MR. Occupational injuries: Setting the stage. In J. Barling & M. R. Frone (Eds.); the psychology of workplace safety. Washington, DC: APA; 2004.
5. Driscoll T, Nelson DI, Steenland K, Leigh J, Concha-Barrientos M, Fingerhut M, Prüss-Ustün A. The global burden due to occupational injury. American Journal of Industrial Medicine. 2005;48(6): 470–481.
DOI:10.1002/ajim.20226
ISSN: 0271-3586
PMID: 16299709
6. Takala J, Hämäläinen P, Saarela KL, Yun LY, Manickam KJTW, Heng P, Tjong C, Kheng, LG. Global estimates of the burden of injury and illness at work in 2012. Journal of Occupational and Environmental Hygiene. 2014;11(5):326–337.
7. Chang SH, Wu TC, Tseng HE. Media mix decision support for schools based on analytic network process. International Journal of Industrial Engineering: Theory, Application and Practice. 2012;19(7): 297–304.
8. Ten Veldhuis JAE, Clemens FHLR, Van Gelder PHAJM. Quantitative fault tree analysis for urban water infrastructure flooding. Structure and Infrastructure Engineering: Maintenance, management, Life-Cycle Design and Performance. 2011;7(11):809-821.
9. Moinuddin KAM, Thomas IR. Reliability of sprinkler system in Australian high rise office buildings. Fire Safety Journal. 2017;63:52-68.

10. Ardeshir A, Amiri M, Ghasemi Y, Errington M. Risk assessment of construction projects for water conveyance tunnels using fuzzy fault tree analysis. International Journal of Civil Engineering. 2014;12(4): 396-412.
11. Ardeshir A, Amiri M, Ghasemi Y, Errington M. Risk assessment of construction projects for water conveyance tunnels using fuzzy fault tree analysis. International Journal of Civil Engineering. 2016;12(4): 396-412.
12. Abdelgawad M, Fayek AR. Comprehensive hybrid framework for risk analysis in the construction industry using combined failure mode and effect analysis, fault trees, event trees, and fuzzy logic. Journal of Construction Engineering and Management. 2015; 138(5):642-651.

Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/93836