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Occupational Health and Safety Risk Assessment Model for Naval Vessels Operating in Niger Delta Waterways

Ido Akpan[1], Ify L. Nwaogazie[2] and Patricks Chinemerem[3]
Centre for Occupational Health Safety and Environment,
University of Port Harcourt, Rivers State, Nigeria.

Abstract
This study involved the designof occupation health and safety risk assessment model for naval ships operating within Niger-Delta, Nigeria. Descriptive and analytical research designs were adopted. Three major accidents prevalent in naval shipsand the associated hazards that caused these accidents were identified using the Nigerian Navy safety ledger (2010-2019).The accidents are Slip and fall accidents, Ship floodingand fire accidents.The risk assessment was conducted by ranking of the hazards based on their risk rating using Conventional Risk Assessment (CRA) and Weighed Risk Assessment (WRA). The risk assessment involved ascertaining the risk rating of the hazard based on likelihood of the hazards to cause harm and the severity of the harm when it occurs. To determine the severity and likelihood of the hazards, questionnaire was designed and administered to the forty-four (44) principal officers in the eleven (11) naval ships and certain assumed fraction (response weight) was assigned to each set of officers based on their rank and experiences. The CRA and WRA were conducted and compared and their results revealed that there were differences between the risk ranking in results from CRA and WRA for all the accidents and the hazards were equally classified using Risk Assessment Matrix (RAM).The three most hazardous events were used to design Fault Tree Assessment (FTA) and Ship Accident Root-cause Evaluation (SHARE) models. The final results showed that the three root-cause of the accidents were poor management, lack of safety awareness and consciousness and violation of rules of safety on-board. It was concluded that three hazards responsible for theaccidents werepoor visibility, lack of safety awareness and violation of safety rules. It was then recommendedthat safety managers on-board naval ships should organize safety workshops for officers to improve their safety awareness.
Key words: *Occupational Health and Safety, Risk Assessment Model, Naval Vessels, Niger Delta*

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I. Introduction

Globally, occupational health and safety, on board the naval ships, is concerned with the tasks of protecting naval officers and other workers on board the naval ship, reducing number of occupational accidents, minimizing insufficient informing, and improving awareness of naval officers, from a multi-disciplinary perspective (Inan et al. 2017). Being among the most crucial processes of occupational health and safety management globally, risk assessment and management has gained significant importance due to some recent regulatory and legal frameworks (Sousa et al. 2015; Guo et al 2019). These frameworks are concerned with several processes which included identification of sources of risks, estimation and description of these identified risks, analysing these risks based on their description and estimation and determination of the control measures before these risks can lead to injury or fatality (Zanko and Dawson, 2012; Gul et al 2017).

In Europe, occupational health and safety in naval units have always been a serious concern because most combat and conventional naval ships are made up of complex arrangements and networks of mechanical and electrical systems, high explosive artillery storages, battle stations and living areas are together in confined and limited space, which necessitates special attention to occupational health and safety for the naval officers and other workers on board. The risk assessment framework for European Union nations is based on managerial goal to mitigate accidents to a minimum level, which resulted in intensive studies for identification of the root causes of accidents (Hu et al., 2007; Guneri et al 2015). For instance, in Turkey, risk assessment and management procedures are integrated into the decision-making process but not considered or researched separately till 2006 when team of researchers initiated detailed research-base which was intended to standardize their risk management procedures at organizational level. During this process, they consider risks on board naval ships in several areas, such as security, safety, ship design, maintenance, project management and logistics, and they finally developed risk assessment and management framework for their naval units (Ayhan & Sinan, 2011).

In Nigerian naval units, risk assessment and management procedures are also integrated into the decision-making process. Similar to what is obtainable in Turkey and it is also not considered as separate entity. Therefore, there is need to conduct detailed studies separately from other decision making processes on these naval units operating in Nigeria which would be concerned with identification of sources of risks, estimation and description of these identified risks, analysing these risks based on their description and estimation, and determination of the control measures before these risks can lead to injury or fatality which entails development of standardized risk management model that could be used in analysing risky situation in these naval units to mitigate accidents.

Nigerian naval units, just like other naval units globally, are exposed to several hazards and accidents, especially the conventional and combat ships, which convey explosives storages, complex arrangement of mechanical and electrical systems, combined battle stations and living compartments, space limitations, simultaneous operational tasks, difficult weather and sea conditions as well as the fact that most Nigerian naval ships are old and out-dated. These situations above create several occupational health and safety risky conditions for naval officers and other workers' on-board naval ships which comprise of but not limited to improper posture and positioning when working, unsafe attitude due to fatigue, exposure to harsh condition, insufficient safety equipment and experience. These risky conditions, based on experience as a naval officer have led to several accidents with numerous casualties.

To mitigate these accidents, Nigerian naval units designed an occupational health and safety framework which is based on conventional Health, Safety and Environment (HSE) procedure and was integrated with other decision making processes for easy assessment and execution. However, this occupational health and safety framework used by these naval units were not effective because their responses to occupational health and safety challenges were mainly on reactive basis; which means that occupational risks and accidents are analysed based on already occurred accidents or incidents and no proactive measures have been developed using suitable occupation health and safety model to address this issue. Therefore, this present study is designed to fill this gap by providing decision makers in these naval units with more proactive, detailed and comprehensive occupational health and safety risk assessment model, using suitable occupational health and safety models, which could be used to manage these situations to pre-empts incidents and accidents before occurrence. Thus, the aim of the study is to design an Occupational Health and Safety (OHS) Risk Assessment Model (RAM) that could be used to identify and mitigate occupational health risks which has potential to cause accidents on-board Nigerian Navy Ships in Niger Delta, Nigeria.The objectives are: (1) to identify the major accidents that occur on-board Nigerian Navy Ships operating in Niger Delta, Nigeria.(2) to determine the various hazards associated with these accidents identified on-board Nigerian Navy ships operating in Niger Delta, Nigeria. (3) to analyse the risk level of the hazards effects using their Severity and Probability of occurrence of these accidents identified above. (4) to develop risk assessment model using outcome of the risk level in objective (3) based on Fault Tree Analysis (FTA). (5) to develop a risk assessment model using outcome of the risk levels based on Ship Accident Root-Cause Evaluation (SHARE) and to conduct detailed risk assessment procedure using these models to develop risk assessment algorithm for the Nigerian Navy ships operating in Niger Delta waterways.

In the shipping industry, Root cause Analysis is employed to try to identify the causes of accidents and incidents, so as to implement corrective and preventative actions that are designed to ensure the incident does not recur. A prudent ship operator will ensure that all incidents that result in injury or damage to people and/or property, or near misses that could lead to such incidents, are thoroughly investigated. Incident investigation (including the investigation of 'near-misses'), can tell an operator much about operational practices and safety culture on board.

From these extensive empirical studies reviewed, it was clear that no empirical work has been conducted to model the OHS risk assessment for Nigerian naval vessels operating within Niger Delta waterways. Thus, this current study will be conducted to develop a model for OHS risk assessment for Nigerian naval vessels operating within Niger Delta waterways using Ship Accident Root-cause Evaluation (SHARE) to identify the main causes of the major accidents.

II. Methodology

2.1 Study Design

The nature of this study requires a combination of descriptive and analytical research designs. Descriptive design was used during the identification of major accidents and their associated hazardsin the naval ships operating within the Niger Delta which covers objectives one and objective two of this study while the analytical design was used to develop risk assessment of the hazards, development of models FTA and SHARE, and compare and combine the two models developed to generate a risk assessment algorithm.

2.2 The Study Population

The population for this study covers the 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). There are 11 Nigerian Navy Ships operating and navigating within these naval bases which are located in the Niger Delta region of Nigeria. They have at least 1 Commander, 1 Executive Officer, 1 Marine Engineering Officer and 1 Weapon Engineering Officer making it at least 4 high ranked officers per ship and a total of 44 officers. Thus the study population is 44.

2.3Sampling Technique

A purposive sampling technique, also known as judgementalsampling 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 above wereselected 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. They includeCommanders, Executive officers, Marine Engineering Officers and Weapon Engineering officers.

These four officers serve as the safety experts in this study because the safety of the on-board officers is directly or indirectly their responsibility and they will be designated at Expert 1, (EX_1), Expert 2, (EX_2), Expert 3, (EX_3) and Expert 4 (EX_4) respectively. Because of different experiences and ranks of these officers, their responses were weighed based on fraction assigned to them, such that officers of high rank which signifies higher experiences are assigned higher weightsas seen in table 1 below.

Table 1: Distribution of the respondents

The Officers	Expert 1 (EX_1)	Expert 2 (EX_2)	Expert 3 (EX_3)	Expert 4 (EX_4)
Number	11	11	11	11
Response Weight	0.4	0.3	0.2	0.1

Source: Researcher Computed Output

2.4 Nature and Source of Data

Both primary and secondary data will be used in this study. The secondary data was the documented accidents and near-miss data from the sampled ships while the primary data will be response of the officers that ware obtained using well-structured questionnaire that was distributed to the sampled officers in the ships. The accident and near-miss data (secondary data) were used to identify the five major accidents encountered by these ships and their corresponding hazards which are occupational health related while the questionnaire was used to ascertain the information on risk assessment specifically the likelihood and Severity of the hazards, and the risk assessment was needed for Fault Tree Analysis (FTA) and Ship Accidents Root-Cause Evaluation (SHARE).

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.

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 are not given the room to freely express their opinion on the subjects of the questions rather they are 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 tables2 and 3 below.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. The Questionnaire comprised of Six (6) sections: A to F.

SECTION A. obtained responses on socio-demographic characteristics of the respondents

SECTION B, **C, D, E and F**were used to obtain responses on the risk assessment of the hazards associated with the three accidents selected,probability of occurrence of these three accidents and the chances of their various causes identified.

Note, there were three sub-sections for each of the main sectioned labelled a 1, 2, 3 and each subsection was used to elicit data on Likelihood and Severity of occurrence of the hazards associated with the three selected accidents. The three major accidents identified are: 1.Slips/fall 2. Flooding/Water ingress 3.Fire accidents.

Table 2: 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; National Patient Safety Agency, 2008)

Table 3: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 as STAGE ONE, STAGE TWO, STAGE THREE and STAGE FOUR.

STAGE ONE: This stage involved using the accident and near-misses' data to identify three major and commonest accidents in the sampled ships based on their number of occurrence. This stage also involvedchecking 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 hazards will be ranked. Example of a typical RAM is shown in table 4 below.

Table 4: A Typical Risk Assessment Matrix showing the various Risk Rating and Color 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

STAGE THREE: The Risk Assessment Matrix and the corresponding hazard effects ranking results were used to design Fault Tree Analysis (FTA) model and Root-cause of the accident based on Ship Accident Root-cause Evaluation (SHARE) model.

STAGE FOUR: This stage involved carrying out comparative analysis on the results of the two model obtained from the FTA and SHARE modelling procedures and then integrate the results of the two to obtain a risk assessment algorithm for the three accidents identified on-board the naval ships operating in Niger Delta waterways.

III. Results

The results of the risk assessment of the naval ships are presented thus; the risk assessment was started by identifying the major accident cases prevalent in naval ships based on recorded statistics of the accident in the naval ships within the Niger-Delta. The three most prevalent accidents, that is accidents with the highest number of occurrences were selected for the risk assessment. See table 5.

Table 5: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	Escape of Harmful Substance	110	
5	Contact	593	
6	Foundering	524	
7	**Ship Flooding//Water Ingress**	**1425**	**2nd**
8	Heavy Weather Damage	86	
9	Hull Failure	39	
10	**Fire Accidents**	**1390**	**3rd**
11	Missing Vessel	6	
12	Capsize/Listing	926	
13	Pollution	50	
	Total	19175	

(Source: Naval Safety Ledger, 2010-2019)

From the Table 5 above the three most prevalent accidents are the accidents with the highest number of occurrence and they include; **Slip and fall Accidents,Ship flooding or Water ingress accidents, and fire 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 we design a 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),

The severity and likelihood of the hazards were obtained from the study respondents and certain assumed fraction (response weight) was assigned to each group of set of respondents based on their rank and experience.The reason for this response weight is forrecognition that the respondents have different experiences and different levels of access to information concerning the safety situation in the ships, hence response from officers with the highest level of experiences and access to information should be given more weight compared to less experienced and restricted officers.See table 1 above.

The risk score was ascertained in two main forms:Theconventional risk score or level and The weight risk score. The conventional risk score was obtained by multiplying the severity score and the likelihood score without considering the response weight. This form of risk assessment assumed that all respondents have equal experiences and equal access to information, thus it is given as:

Conventional risk score = S (severity) × L (likelihood)

The weight risk score which is obtainedby multiplying the severity score and the likelihood score and also the response weight of the respondent. This form of risk assessment takesinto consideration the fact that the

respondents have different experiences and access to information, thus high experienced and high access respondents are given high response weight than lower experienced respondent.This means that:
Weight risk score = S (severity) × L (likelihood) × RW (Response Weight)

3.1 Result of Risk Assessment for Slip and Fall Accident

The hazards associated with slip and fall accidentsare presented in table 6 below.

Table 6. Hazards Associated with Slip and Fall Accidents

S/N	Hazards
1	Excessive alcohol and hard-drug 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)

The conventional risk score obtained based on responses from respondents on the hazards associated with "Slip and Fall Accident" is given in table 7 below. The arrangement on the hazard table 6 above is such that there are eleven (11) hazards considered and they are represented with 1 to 11 respectively.

Table 7 Conventional Risk Assessment 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	3RD
2	15.90	17.09	17.27	16.55	16.70	6TH
3	13.90	15.90	16.55	14.55	15.23	9TH
4	19.73	18.64	16.72	15.27	17.59	4TH
5	12.27	14.55	16.55	13.64	14.25	10TH
6	11.64	12.74	15.27	13.55	13.30	11TH
7	21.90	21.09	18.36	19.73	20.27	2ND
8	14.90	19.64	16.82	17.18	17.14	5TH
9	16.18	17.18	15.73	15.27	16.09	7TH
10	14.90	13.64	15.55	11.55	13.90	8TH
11	21.36	21.45	20.55	20.73	21.02	1ST

Source; Researcher Computed output

From table 7 above it was observed that the hazard with highest risk score is hazard 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 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."

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

In terms of their risk levels, a risk assessment matrix design by National Patient Safety Agency (2008) will be used to assess the risk level of the hazards in this table 7. Note; in this table 7, consequence is synonymous to severity while probability is synonymous to likelihood.

Based on this Risk Assessment Matrix in table 7 above and the risk grading, it is observed that hazard number 1,2,3,4,7,8,9 and 11 which corresponds to " Excessive alcohol and hard-drugs, 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 highly risky hazard**.

Table 8: Weight Risk Assessment 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	9.16	6.19	3.73	1.73	5.20	2ND
2	6.36	5.13	3.45	1.66	4.19	6TH
3	5,56	4.77	3.31	1.46	3.78	8TH
4	7.89	5.59	3.34	1.53	4.59	4TH
5	4.91	4.37	3,31	1.36	3.49	10TH
6	4.66	3.82	3.05	1.36	3.22	11TH
7	8.76	6.33	3.67	1.97	5.18	3RD
8	5.96	5.89	3.36	1.72	4.23	5TH
9	6.47	5.15	3.15	1.53	4.08	7TH
10	5.96	4,09	3.11	1.16	3.58	9TH
11	8.54	6.44	4.11	2.73	5.45	1ST

Source; Researcher Computed Output

The table 8 above shows the risk assessment score based on weighted risk assessment criteria. When the results of the conventional and weighted risk scores were compared it was observed that there were changes in hazard 1, hazard 3, hazard 7 and hazard 10.See table 9 below, which confirms the fact that considering the experiences and exposure of the respondents in making risk assessment would alter the risk score and ultimately the risk ranking which would, in general give more accurate assessment, thus based on the weight risk assessment ranking,
Hazard 11> hazard 1 > hazard 7 > hazard 4 > hazard 8 > hazard 2 > hazard 9 > hazard 3 > hazard 10 > hazard 5 and > hazard 6.

Table 9: Ranking order of Weighed Risk Score (WRS) and Conventional Risk Score CRS)

HAZARDS	RANKING BASED ON CRS	RANKING BASED ON WRS
1	3RD	2ND
2	6TH	6TH
3	9TH	8TH
4	4TH	4TH
5	10TH	10TH
6	11TH	11TH
7	2ND	3RD
8	5TH	5TH
9	7TH	7TH
10	8TH	9TH
11	1ST	1ST

Source; Researcher Computed Output
From this assessment, hazard 11, hazard 1 and hazard 7 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 Three Analysis as showed in figure 1 below.

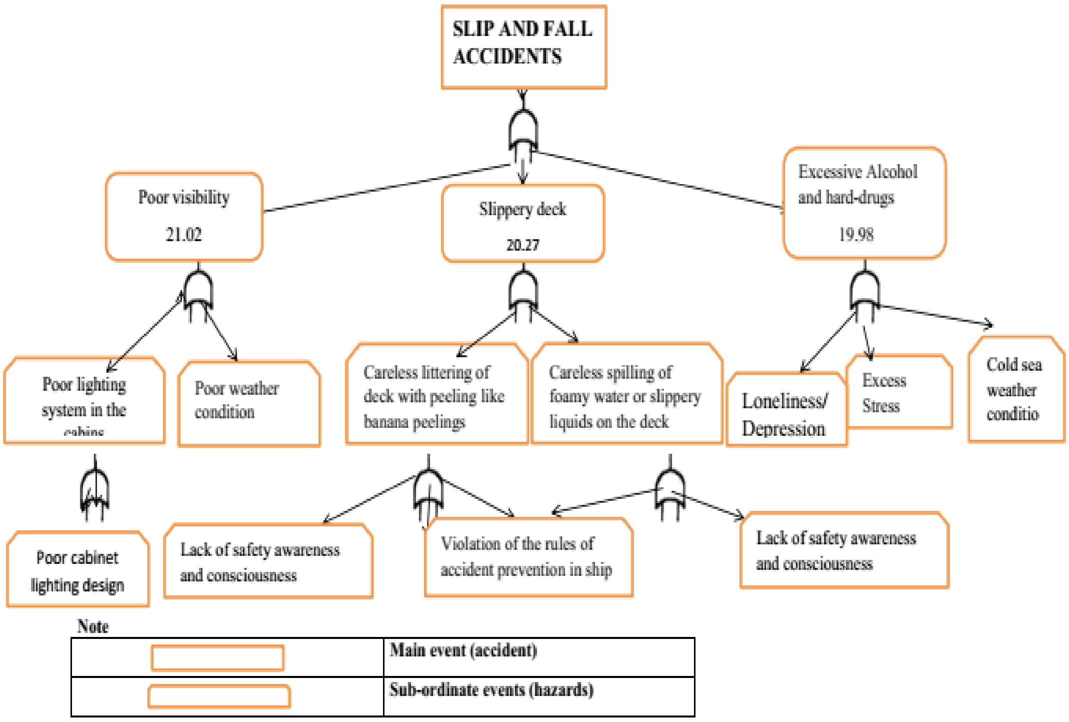

Figure 1: Fault Tree Analysis Chart for Slip and Fall Accidents

3.2:Risk Assessment for Ship Flooding/Water Ingress Accident

The hazards associated with **Ship Flooding/Water Ingress Accident**are presented in table 10 below:

Table10 Hazards Associated with Ship Flooding/Water Ingress Accident

S/N	HAZARDS
1	Cabinet Leakage due to rusting
2	Cabinet Leakage due to chemical attack
3	Cabinet Leakage due to explosion
4	Adverse Weather
5	Corrosion attack
6	Collision

(Source: Naval Safety Ledger, 2010-2019)

The conventional risk score obtained based on responses from respondents on the hazards associated with S**hip Flooding/Water Ingress Accident**is given in table 11 below.The arrangement on the hazard table is such that there are six (6) hazards considered and they are represented with 1 to 6 respectively.

Table 11: Conventional Risk Assessment Results for Ship Flooding/Water Ingress Accident

HAZARDS	Average Risk Score EX1	Average Risk Score EX2	Average Risk Score EX3	Average Risk Score EX4	Overall average Risk score	RANKING
1	16.67	19.09	18.67	17.90	18.08	1st
2	19.57	17.89	16.67	15.90	17.51	2nd
3	15.45	19.08	14.67	18.97	17.04	3rd
4	9.67	14.78	17.09	14.80	14.09	6th
5	13.60	16.13	18.34	15.60	15.92	5th
6	16.32	18.22	13.87	17.07	16.37	4th

Source: Researcher Computed Output.

From table 11 above, it was observed that the hazard with highest risk score was hazard 1 which corresponds to cabinet leakage due to rusting with risk score of 18.08. This was followed by hazard 2 corresponding to cabinet leakage due to chemical attack with risk score of 17.51, then followed by hazard 3 which corresponds to cabinet leakage due to explosion with risk score of 17.04.The hazard with least risk score is hazard 4 which corresponds to adverse weather with risk score of 14.09.

This means that from the responses of the respondents whereby all respondentswere assumed to have equal safety experiences and exposures, cabinet leakage due to rusting was ranked as the riskiest hazard to cause ship flooding and water ingress accidents followed by cabinet leakage due to chemical attack and cabinet leakage due to explosion respectively while adverse weather was considered the least risky hazard.
In terms of their risk level, a Risk Assessment Matrix (RAM) designed by National Patient Safety Agency (2008) was used to assess the risk level of the hazards as seen in table 12. Note; in this table 12, consequence is synonymous to severity while probability is synonymous to likelihood.

Table 12: A Typical Risk Assessment Matrix showing the various Risk Score and Color 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 Patience 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

Based on this Risk Assessment Matrix above and the Risk grading, it is revealed that hazard 1, hazard 2, hazard 3, hazard 5 and hazard 6 which correspond to leakage of the cabin due to rusting, leakage of the cabin due to chemical attack, leakage of cabin due to explosion, corrosion attack and collisions respectively are all under **extremely risky hazard level** while hazard 4 which corresponds to adverse weather is between **highly risky and extremely risky hazard.**

Table 13: Weighed Risk Assessment Results for Ship Flooding/Water ingress Accident

HAZARDS	Average Risk Score EX1	Average Risk Score EX2	Average Risk Score EX3	Average Risk Score EX4	Overall average Risk score	Ranking
1	5.88	5.73	3.73	1.79	4.28	2nd
2	7.83	5.37	3.33	1.59	4.53	1st
3	6.18	5.72	2.93	1.90	4.18	3rd
4	3.87	4.43	3.42	1.48	3.30	6th
5	5.44	4.84	3.67	1.56	3.88	5th
6	6..53	5.47	2.77	1.71	4.12	4th

Source; Researcher Computed Output.

The table 13 above shows the risk assessment score based on Weighed Risk Assessment (WRA) criteria. When the results of the Conventional Risk Score (CRS) and Weighed Risk Scores (WRS)were compared, it was observed that there were changes between hazard 1 and hazard 2 as seen in table 14 below.

Table 14: Ranking order of weighed risk score and conventional risk score for Ship Flooding/water Ingress Accidents

HAZARDS	WEIGHED RISK SCORE RANKING	CONVENTIONAL RISK SCORE RANKING
1	2nd	1st
2	1st	2nd
3	3rd	3rd
4	6th	6th
5	5th	5th
6	4th	4th

Source; Researcher Computed Output

This confirmed the fact that considering the experiences and exposures of the respondents in making risk assessment of hazards responsible for ship flooding/water ingress accidents, there will be a significant change in risk assessment score and ultimately changes the risk ranking which would, in general, give more accurate risk assessment. Therefore, the most accurate risk ranking order for the hazard based on weighed risk score is given as

Hazard 2 > hazard 1 > hazard 3 > hazard 6 > hazard 5 > hazard 4

From this hazard ranking above, hazard 2, hazard 1 and hazard 3 are the three riskiest hazards responsible for Ship Flooding/water ingress accidents in naval ships within Niger-Delta Nigeria. Therefore, these three hazards were used to carry out Fault Tree Analysis (FTA) as showed in figure 2 below:

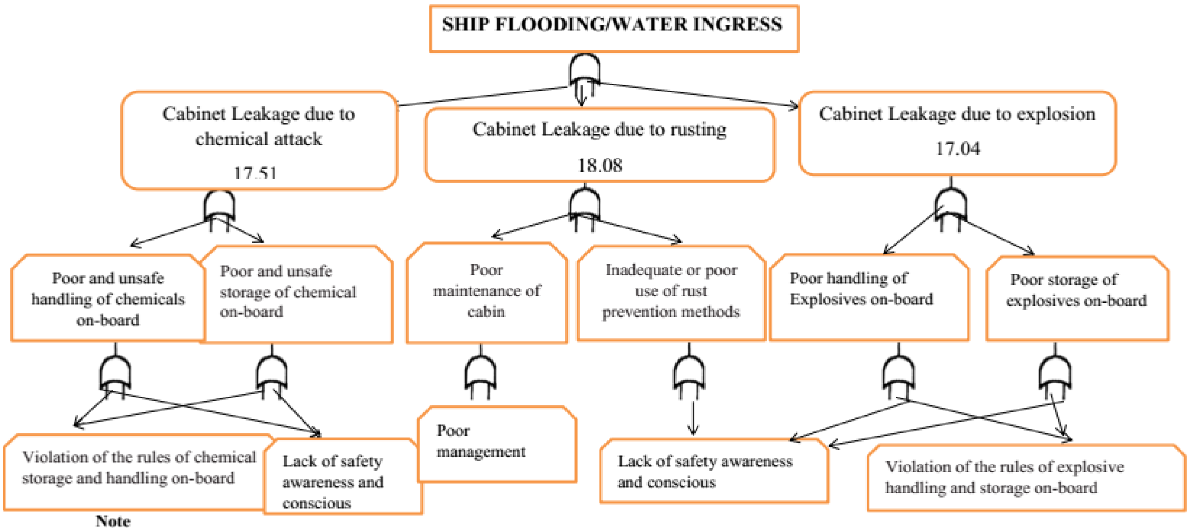

Figure 2: Fault Tree Analysis Chart for ship flooding/water ingress

3.3 Risk Assessment for Fire Accidents

The hazards associated with **Fire Accident** are presented in table 15 below:

Table 15: Hazards Associated with Fire Accident

S/N	HAZARDS
1	Working at confined space
2	Unsafe behaviour due to fatigue
3	Lack of safety awareness and consciousness
4	Inappropriate use of electrical equipment
5	Poor electrical connections
6	Exposed hot surfaces
7	Poor warning signage
8	Excessive alcohol and drug use
9	Improper use of safety equipment
10	Violation of rules of accident prevention
11	Unsafe handling of Flammables
12	Un-Insulated live-wires
13	Unsafe handling of explosive/armaments

(Source:Naval Safety Ledger, 2010-2019).

The conventional risk score obtained based on responses from respondents on the hazards associated with **FireAccident** is given in table 16 below and the arrangement on the hazard table is such that there are thirteen (13) hazards considered and they are represented with 1 to 13 respectively.

Table 16: Conventional Risk Assessment Results for Fire Accident

HAZARDS	Average Risk Score EX1	Average Risk Score EX2	Average Risk Score EX3	Average Risk Score EX4	Overall average Risk score	Ranking
1	12.24	14.56	16.09	15.89	14.70	8TH
2	10.56	15.87	13.56	12.36	13.09	10TH
3	10.24	14.89	15.10	13.58	13.45	9TH
4	20.19	19.08	20.09	22.23	20.40	3RD
5	15.48	17.37	17.31	19.36	17.38	5TH
6	15.68	16.22	15.85	19.06	16.70	7TH
7	7.89	8.89	13.07	11.27	10.27	12TH

8	7.24	9.89	11.16	10.12	9.35	13TH
9	16.44	15.15	18.75	15.93	16.89	6TH
10	7.34	10.89	11.31	11.96	10.38	11TH
11	23.46	21.09	22.40	21.89	22.21	1ST
12	19.87	20.21	19.89	21.08	20.26	4TH
13	21.08	19.69	20.78	22.09	20.91	2ND

Source: Researcher Computed Output.

From table 16 above it was observed that the hazard with highest risk score was hazard 11 which corresponds to unsafe handling of flammables with risk score of 22.21 followed by hazard 13 corresponding to unsafe handling of explosives with risk score of 20.91, then followed by hazard 4 which corresponds to inappropriate use of electrical equipment with risk score of 20.40, while the hazard with least risk score is hazard 8 which corresponds to excessive useofalcohol and hard drugs with risk score of 9.35.

This means that from the responses of the respondents whereby all respondentswere assumed to have equal safety experiences and exposures, unsafe handling of flammables was ranked as the riskiest hazard to cause fire accidents in ships followed by unsafe handling of explosives and inappropriate use of electrical equipment respectively while excessive alcohol andhard drug usewas considered the least risky hazard among the hazards considered.

In terms of their risk level, a RAM designed by National Patience Safety Agency (2008) was used to assess the risk levels of the hazards as seen in table 17 below.

Note; in this table 17, consequence is synonymous to severity while probability is synonymous to likelihood.

Table 17: A Typical Risk Assessment Matrix showing the various Risk Score and Color 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 Patience 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

Based on this RAM above and the risk grading, it is revealed that hazard 4, hazard 5, hazard 6, hazard 9, hazard 11, hazard 12 and hazard 13 which correspond to inappropriate use of electrical equipment, poor electrical connections, exposed hot surfaces, improper use of safety equipment, unsafe handling of flammables, un-insulated or live wire exposure and unsafe handling of explosives respectivelyare all under **extremely risky hazard level** while hazard 4 which corresponds to inappropriate use of electrical equipment is between **highly risky and extremely risky** hazard.Hazard 1, hazard 2 and hazard 3 which correspond to working at confined space, unsafe behaviour due to fatigue and lack of safety awareness and consciousness respectively are considered to exist between **extremely risky and high risk** hazard whereas hazard 7, hazard 8 and hazard 10 which correspond to poor warning signage, excessive alcohol and hard drug use and violation of rules of accident preventionrespectively fall under **high risk** hazard.

Table 18: Weighed Risk Assessment Results for Fire Accident

HAZARDS	Average Risk Score EX1	Average Risk Score EX2	Average Risk Score EX3	Average Risk Score EX4	Overall average Risk score	Ranking
1	4.90	4.36	3.22	1.59	3.52	8^{TH}
2	4.22	4.76	2.71	1.24	3.23	9^{TH}
3	4.10	4.47	3.02	1.34	3.22	10^{TH}
4	8.08	5.72	4.02	2.22	5.01	4^{TH}
5	6.19	5.21	3.46	1.94	4.20	5^{TH}
6	6.27	4.87	3.17	1.91	4.06	7^{TH}
7	3.16	2.67	2.61	1.13	2.39	12^{TH}
8	2.90	2.97	2.23	1.01	2.28	13^{TH}
9	6.58	4.55	3.75	1.59	4.12	6^{TH}
10	2.94	3.27	2.26	1.19	2.42	11^{TH}
11	9.38	6.33	4.48	2.19	5.60	1^{ST}
12	7.95	6.06	3.98	2.11	5.02	3^{RD}
13	8.43	5.91	4.16	2.21	5.18	2^{ND}

Source: Researcher Computed Output.

Table 18 above shows the risk assessment score based on WRA criteria for fire accident. When the results of the Conventional Risk Scores (CRS)and WeighedRisk Scores (WRS) were compared,it was observed that there were changes in hazard 2, hazard 3, hazard 4 and hazard 12 as seen in table 19 below:

Table 19: Ranking order of weigh risk score and conventional risk score for fire accident

HAZARDS	RANKING BASED ON WRS	RANKING BASED ON CRS
1	8^{TH}	8^{TH}
2	9^{TH}	10^{TH}
3	10^{TH}	9^{TH}
4	4^{TH}	3^{RD}
5	5^{TH}	5^{TH}
6	7^{TH}	7^{TH}
7	12^{TH}	12^{TH}
8	13^{TH}	13^{TH}
9	6^{TH}	6^{TH}
10	11^{TH}	11^{TH}
11	1^{ST}	1^{ST}
12	3^{RD}	4^{TH}
13	2^{ND}	2^{ND}

Source: Researcher Computed Output

In table 19 above, hazard 2 which was ranked 10^{th} in the CRS changed to 9^{th} in the WRS, hazard 3 which was ranked 9^{th} in the CRS was ranked 10^{th} in the WRS, hazard 4 which was ranked 3^{rd} in the CRS was changed to rank 4^{th} in WRS whereas hazard 12 ranked 4^{th} based on CRS is now upgrade to rank 3^{rd} in WRS ranking. These rearrangement or changes observed in these ranking confirm the fact that in conducting risk assessment of fire accidents in naval ships, there is significant change in risk assessment score and ultimately changes the risk ranking when experiences and exposures of the respondents are factored into risk assessment scoring and this will give more accurate risk assessment of the hazard considered. Therefore, the most accurate risk ranking order for the hazard based on WRS is given as:

Hazard, 11 > hazard, 13 > hazard, 12 > hazard, 4 > hazard, 5 > hazard 9 > hazard 6 > hazard 1> hazard 2, > hazard 3 > hazard 10 > hazard 7 > hazard 8

From this hazard ranking above, hazard 11, hazard 13 and hazard 12 are the three riskiest hazards responsible for fire accidents in naval ships within Niger-Delta, Nigeria. Therefore, these three hazards were used to carry out Fault Three Analysis (FTA) as showed in figure 3 below:

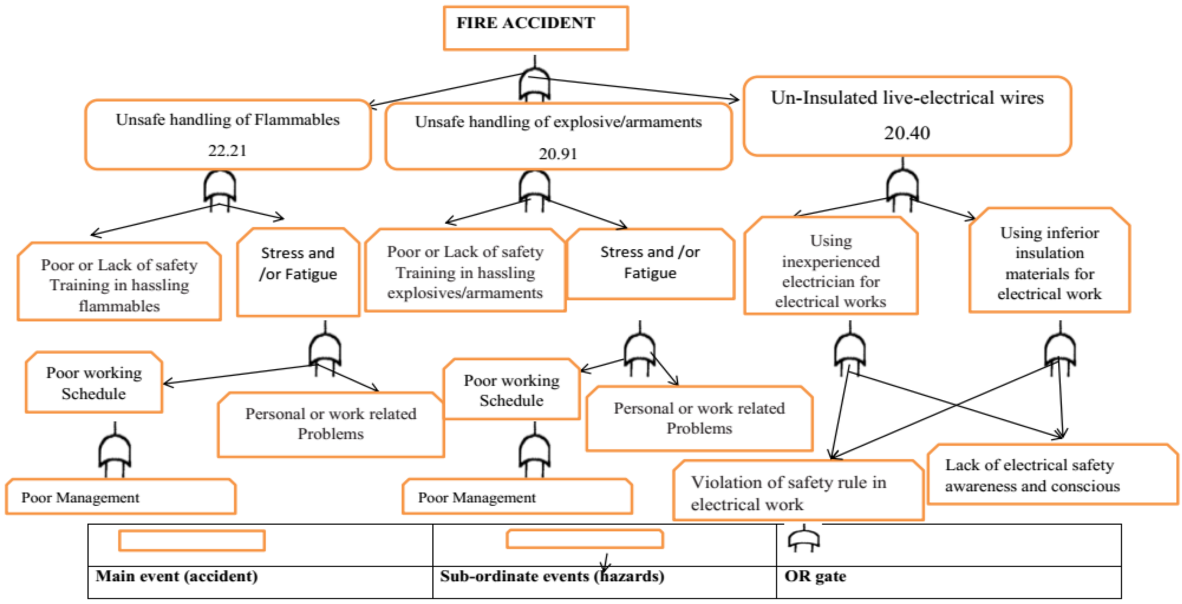

Figure 3: Fault Tree Analysis Chart for Fire Accidents

3.4: The Ship Accidents Root-cause Evaluation (SHARE)

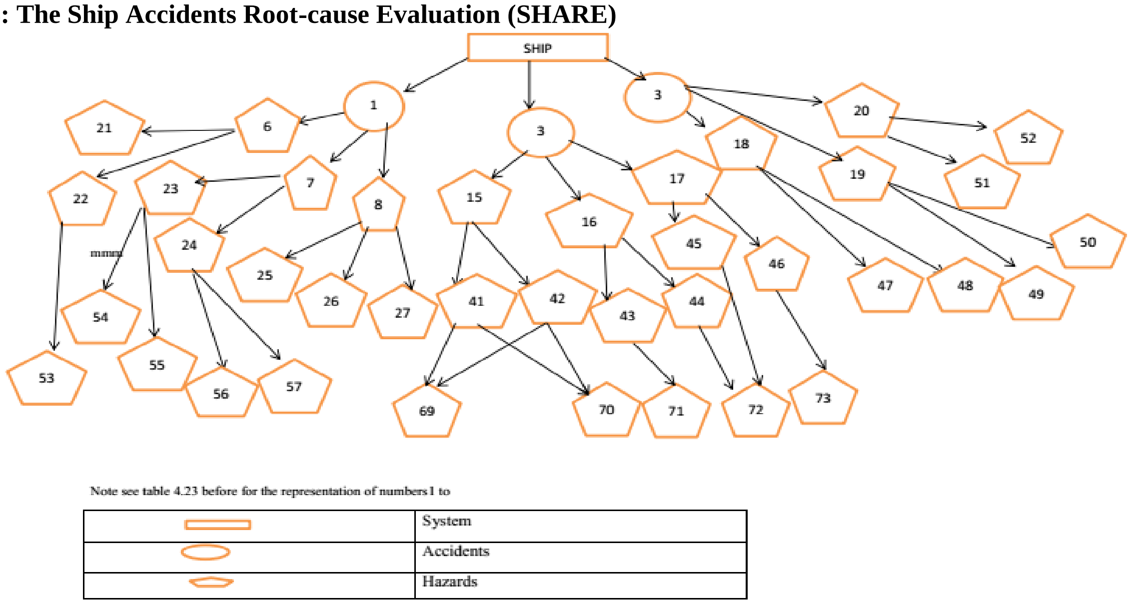

Figure 4: Ship Accident Root-cause Evaluation (SHARE) Chart

Table 20: The numbers and their corresponding events and hazards in the SHARE chart

S/N	Events and hazards
1	Slip and fall Accidents
3	Ship Flooding/Water Ingress Accident
3	Fire Accidents
6	Poor visibility
7	Slippery deck
8	Excessive alcohol and hard drug use
15	Lack of personal protective equipment
16	Cabinet Leakage due to chemical attack
17	Cabinet Leakage due to rusting
18	Cabinet Leakage due to explosion
19	Unsafe handling of Flammables
20	Unsafe handling of explosive/armaments
21	Un-Insulated live-electrical wires
22	Poor lighting system in the cabins
23	Poor weather condition
24	Careless littering of deck with peeling like banana peelings

25	Careless spilling of foamy water on the deck
26	Loneliness/Depression
27	Excess Stress
41	Cold sea weather condition
42	Poor and unsafe handling of chemicals on-board
43	Poor and unsafe storage of chemical on-board
44	Poor maintenance of cabin
45	Inadequate or poor use of rust prevention methods
46	Poor handling of Explosives on-board
47	Poor storage of explosives on-board
48	Poor or Lack of safety Training in hassling flammables
49	Poor or Lack of safety Training in hassling explosives/armaments
50	Stress and /or Fatigue
51	Using inexperienced electrician for electrical works
52	Using inferior insulation materials for electrical work
53	Poor cabinet lighting design
54	Lack of safety awareness and consciousness
55	Violation of the rules of accident prevention in ship
56	Lack of safety awareness and consciousness
57	Violation of safety rules in electrical work
69	Lack of electrical safety awareness and consciousness
70	Poor Management
71	Working at confined space
72	Poor Warning signage
73	Violation of safety rules in electrical work

From the FTA and the SHARE, it was observed that the most predominant end-point hazards responsible for other hazards and the accidents are mostly, poor management, lack of safety awareness and consciousness and finally violation of safety rules. This point to the simple fact that the main accidents concerned in Naval ships operating within the Niger-Delta are because of three major Root-Cause, namely:

1) Poor safety management on the part of the naval personnel
2) Lack of safety awareness and consciousness on the part of the naval personnel
3) Violation of safety rules and regulation on-board the naval ships by the naval personnel

3.5: The Proposed Risk Assessment Model for Nigerian Naval Ship

The proposed risk assessment model for the Nigerian naval ships, as developed and shown in figure 4 below is based on integrating the results of the risk assessment carried out using FTA and SHARE. The proposed risk assessment model was based on the CRA stages which started with identification of the three major accidents prevalent in the Nigerian naval ships and the hazards that are associated with the accidents. The hazards where ranked using RAM based on the value of their risk rating obtained by considering the likelihood of the hazard to cause accidents and the severity of the accident if they occur.Three most hazardous events were identified for each of the three accidents and their subsequent hazardous events were followed to ascertain the root-cause of the accidents using the FTA and SHARE. Finally, the proposed model was developed as shown below using the Ships (system), the threeaccidents (the main events), the corresponding most hazardous events (intermediate event) and the root-cause of the accidents (underdeveloped event). Base on theidentified root-cause of accidents on board the naval ships, recommendations will be made. The diagram of the proposed model below in figure 5 revealed details of the accidents considered, the three most hazardous events that cause the accidents and the corresponding root-cause of the hazardous events.

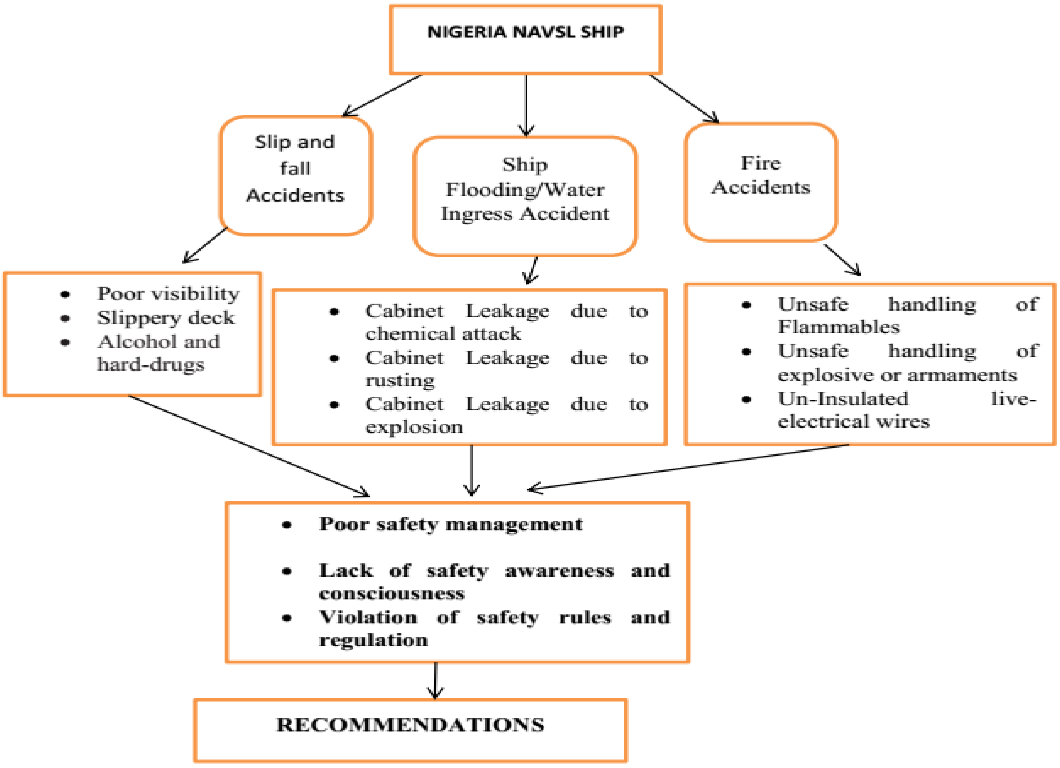

Figure 5: Diagram of the proposed risk assessment model for naval ships operating in Niger-Delta waterways.

IV. Discussion

Based on the data obtained from the NigerianNavy safety ledger, three major accidents were identified based on their percentage of occurrence with respect to the entire accident cases that occurred from year 2010 to year 2019.The accidents identified wereslip and fall accident, Ship flooding/water ingress and fire accidents. The hazards that are associated with these accidents were also sourced from NigerianNavy safety ledger 2010-2019. Thus risk assessment was conducted on these hazards using the responses obtained from the four principal officers in the 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 two techniques, namely Conventional Risk Assessment (CRA) and the Weighed Risk Assessment (WRA) and the results obtained are discussed as follows:

For the slip and fall accident, there are eleven associated hazardsidentified which 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 hazard with highest risk score was 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 least risky hazard with risky score of 13.30. This means that from the responses of the respondents, whereby all respondentswere 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 drugswhile improper use of safety equipment was considered the least risky hazard. The result of WRA was compared to CRA result and there was notable change of which the most significant was that excessive alcohol and harddrug use replaced slippery deck as second riskiesthazard.This confirmed the fact that considering the experiences and exposures of the respondents in making risk assessment would alter the risk score and ultimately the risk ranking which would, in general give more accurate assessment.Thus based on the WRA ranking, poor visibility, excessive use of alcohol and hard drugs and slippery deck which were the three riskiest hazards were used to design FTA and SHARE models. These models both point to the fact that poor management, lack of safety awareness and consciousness and violation of safety rules are main or root cause of slip and fall accidents. This study aligned with the work of Ardeshir et al. (2016) who applied FTA in order to identify the main causes of events and incidents in construction of water conveyance tunnels. This result also concurred with study carried out by Jimenez (2010) titled "Application of

Root Cause Analysis in Marine Accident Investigation: Case Study SMIT Transport & Heavy Lift Europe" which was aimed at uncovering root causes of accidents that have resulted in damages to ships, and they revealed that seasonal change and phycological state of the crew members are mainly the root cause of accidents in the ship

For ship flooding/water ingress accidents, the hazards considered which were also obtained from NigerianNavy safety ledger were cabinet leakage due to rusting, cabinet leakage due to chemical attack, cabinet leakage due to explosion, adverse weather,corrosion attack and collision. The CRA analysis showed that three riskiest hazards to cause ship flooding were cabinet leakage due to rusting, cabinet leakage due to chemical attack, cabinet leakage due to explosion with risk scores of 18.08, 17.51 and 17.04 respectively while the least risky hazard was adverse weather with risk score of 14.06. When this CRA result was compared with WRA result, it was revealed that there was notable change with most significant beingcabinet leakage due to rusting displaced by cabinet leakage due to chemical attack.This confirmed the fact that considering the experiences and exposures of the respondents in making risk assessment would alter the risk score and ultimately the risk ranking which would, in general give more accurate assessmentbased on the WRA ranking. Though the three riskiest hazards remained the same and were used to design FTA and SHARE models, however, both models pointed to the fact that poor maintenance of cabin (poor management), lack of safety awareness and consciousness and violation of safety rules are main or root cause of flooding/water ingress accidents. This study also concurred with work of Moinuddin and Thomas (2017) 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. This result also concurred with study carried out by Jimenez (2010) titled "Application of Root Cause Analysis in Marine Accident Investigation: Case Study SMIT Transport & Heavy Lift Europe" which was aimed at uncovering root causes of accidents that have resulted in damages to ships, and they revealed that seasonal change and phycological state of the crew members are mainly the root cause of accidents in the ship

Finally considering fire accidents, the hazards involved as sourced from NigerianNavy safety ledgerare shown in table 15. CRA was conducted and the results showed that the hazard with highest risk score wasunsafe handling of flammables with risk score of 22.21, followed by unsafe handling of explosives with risk score of 20.91, and inappropriate use of electrical equipmentwith risk score of 20.40 while the hazard with least risk score was hazard 8 which corresponds to excessive use of alcohol and hard drugs with risk score of 9.35. The result was compared with result from WRA and there were some notable changes but most significant was that inappropriate use of electrical equipment was displaced in 3rd position by un-insulated electric wire which also confirmed the fact that considering the experiences and exposures of the respondents in making risk assessment would alter the risk score and ultimately the risk ranking which would, in general give more accurate assessment.Thus based on the WRA ranking, the three riskiest hazards were used to design FTA model and SHARE model. However, both models also pointed to the fact that poor management, lack of electrical safety awareness and consciousness and violation of safety rules were main or root cause of electrical accidents.This work also aligned with another work by Abdelgawad and Fayek (2015) 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. This result also concurred with study carried out by Jimenez (2010) titled "Application of Root Cause Analysis in Marine Accident Investigation: Case Study SMIT Transport & Heavy Lift Europe" which was aimed at uncovering root causes of accidents that have resulted in damages to ships, and they revealed that seasonal change and phycological state of the crew members are mainly the root cause of accidents in the ship

In summary, it has been confirmed from the results of this study that based on the three most prevailing accidents in the Nigerian naval ships operating within Niger-Delta waterways, which includes slip and fall accident, ship flooding/water ingress accidents and fire accidents, there are three major root cause of these accidents and they are poor management, lack of safety awareness and consciousness and violation of rules of safety on-board.

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