



Occurrence Probability Coefficients of Risk of Hazards in Shipwreck Removal Operations in Nigeria's Waterways

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ABSTRACT

The study evaluated the occurrence probability of risk of hazards in shipwreck removal operations in Nigeria waterways. The objective of the study was to estimate the occurrence probability of hazards of shipwreck removal operations in Nigeria and rank the hazards in decreasing order of occurrence probability. The study used ex-post facto research design, employing time series secondary data. The time series data on the frequency of risk and hazards types in shipwreck removal operations in Rivers State and Bayelsa State coastal regions of Nigeria, was obtained from the operations department of Humber Marine Werks Ltd, the salvage company used as case study. The statistical method of occurrence probability theory was used to analyze the data obtained. The result of the study indicates that, operational hazard types which include Sudden failure of equipment/downtime (SFE), Human error (HE), Fleet traffic within operating location FTOL), etc., have the highest occurrence probability of 27%. This is followed by technical risk/hazards types which include Hazards related to poor use, inadequacy/lack of requisite equipment and tools (HTE); Hazards related Lack of/poor technical know-how and experience (LTH), Risks related to equipment maintainability problems (REM), and Risks related to poor work procedure (RPWP) with occurrence probability of 23%. Risk of Environmental hazards is third in the ranking with occurrence probability of 21%, followed by natural and security risks types. The implications on policy development were discussed and recommendations were preferred on the basis of the research findings.

1.0 INTRODUCTION

The persistent inability of the Nigeria Ports Authority (NPA), the Nigeria Maritime Administration and Safety Agency (NIMASA), and the Nigeria Inland Waterways Authority (NIWA) to guarantee wreck-free navigable waters and channels in Nigeria by effectively removing shipwrecks left in the navigable waters is one of the numerous obstacles to the safety of navigation in Nigerian waterways. According to Sulaimon (2021), there are more than 3,000 shipwrecks scattered throughout Nigeria's coastline alone. This implies that it is risky to travel through areas of water where shipwrecks are common. This could result in a higher frequency of maritime accidents and the socioeconomic repercussions that follow. Consequently, the maritime transportation industry's sustainable growth will be able to significantly support the economic goals of the country is hampered. According to Sulaimon (2021), the failure of indigenous companies that were previously awarded wreck removal contracts in Nigeria to successfully execute such contracts is closely related to the issue of the preponderance of shipwrecks in Nigeria's waterways. This is because the contractors were exposed to marine perils and hazards associated with wreck removal in the marine environment, which they (the contractors) did not anticipate before the contract was awarded (Sulaimon, 2021; Chima, 2017; Olariwaju, 2014).

Therefore, there appears to be a problem with the contractors' and coastal authorities' lack of empirical data regarding the incidence, frequency, and/or likelihood of risk kinds and categories of hazards related to shipwreck removal operations in Nigeria. As a result, the majority of Nigeria's prior wreck removal contracts have gone to local businesses that lack the necessary expertise and a thorough awareness of the dangers and hazard kinds involved in shipwreck removal operations. The result is the termination of the wreck removal operation whose contract has already been awarded and paid for when these organizations actually face the dangers involved in wreck removal and are exposed to the related hazards in the marine environment.

The repercussions of abandoning the wreck removal operation include violations of maritime safety standards, an increase in accident frequency, and ensuing socioeconomic repercussions.

Local wreck removal companies must therefore have a real-time understanding of the risks and related hazards that are associated with and causing disruptions of wreck removal operations in order to carry out a shipwreck removal operation successfully. They must also build empirical information on each risk type associated with wreck removal operations in order to determine the probability of occurrence of each risk and hazard type in order to understand the level of exposure of workers to the hazard types and the impacts. In order to ensure a successful wreck removal operation and minimize the number of injuries linked to each risk and hazard type, this will guarantee that the risks and hazards related to wreck removal operations in Nigerian waters are proactively controlled.

A number of elements present risks and sources of hazards to shipwreck clearance operations, according to Buerbe (2006) and Palmgren (2001). According to Palmgren (2001), a high rate of occupational injury and death linked to a wreck removal operation could jeopardize the operation's success. These factors include a lack of technical know-how, inexperience, inadequate and inadequate equipment, malfunctioning equipment, maintenance problems, equipment failure, etc.

In addition to exposing operators to risks and hazards (such as injury, death, drowning, etc.), other factors include hydrographic conditions and issues related to surface and underwater conditions during wreck removal, geologic issues related to adopting an excavation approach and wreck removal techniques, and atmospheric weather conditions. These factors also influence the occurrence of hazards in wreck removal operations. Studies by Fowler, Jones, and Vine (1995) further demonstrated that wreck removal is linked to environmental pollution risks, specifically oil pollution risk, since most wrecks have the potential to leak oil into the marine environment during removal, putting the operators (spillers) at risk for compensation and third-party claims.

Based on the aforementioned, the study classified the risks and hazards associated with shipwreck clearance operations based on the main causes of those risks and hazards, as indicated in table 1 below:

Table 1: Primary Sources of Risks of Hazards (Risk Factors) Associated with Wreck Removal Operations

s/n	Risk/hazard type/grouping	Specific/Individual risk/causes associated with each risk type/group	Associated occupational hazards and effects
1	Technical risks (TR)	i. Hazards related to poor use, inadequacy/lack of requisite equipment and tools (HTE) ii. Hazards related Lack of/poor technical know-how and experience (LTH) iii. Risks related to equipment maintainability problems (REM) iv. Risks related to poor work procedure (RPWP)	(i) Occupational Injury to operators (ii) Death (iii) Environmental damage, etc
2	Natural risks (NR)	(i) Hydrological conditions related to underwater and surface water operations in removal of wrecks in the marine environment where wrecks exist (HUSO) (ii) Geological conditions and operations (geological operations associated with the digging and excavation of sunken and underwater/submerged wrecks conditions (GESW) (iii) Atmospheric weather conditions prevailing in the marine environment to which the operators are exposed induces risk of occupational injury and death that hamper the wreck removal exercise (AWRW)	(iv) Occupational Injury to operators (v) Death (vi) Environmental damage, etc
3	Operational risks (OR)	i. Sudden failure of equipment/downtime (SFE) ii. Human error (HE) iii. Fleet traffic within operating location FTOL) Etc.	(i) Occupational Injury to operators (ii) Death (iii) Environmental damage, etc
4	Security risks (SR)	(i) Pirate attacks and kidnap for ransom (PAKR) (ii) Attack and Assault on operators (AAO) (iii) Deliberate Shooting at and killing of operators (DSKO)	(iv) Kidnap for ransom (v) Missing of crew (vi) Trauma and assault (vii) Occupational Injury to operators (viii) Death, etc.
5	Environmental pollution Risk (ER)	(i) oil pollution (OP) (ii) pollution by noxious chemical substances (PNCS) (iii) pollution by other dangerous materials types other than oil and noxious chemicals (PDMT)	(iv) environmental damage claims by third parties (v) damage to biodiversity (vi) Occupational Injury to operators (vii) Death, etc

Source: Prepared by the Author.

In order to prioritize the implementation of risk mitigation measures, it is crucial to ascertain the occurrence probability coefficient of each risk and hazard type in order to limit exposure to the effects of the related hazards and the occurrence of the identified risk types associated with wreck removal. In order to categorize, rank, and prioritize the elimination of the risks and hazards types and guarantee successful wreck removal operations, it is crucial to have a thorough understanding of the occurrence probability coefficients of the risks and hazard types to which wreck removal

contractors and workers are exposed in the Nigerian maritime sector.

1.2 Aim and Objectives of the Study

The aim of the study is to assess Occurrence Probability Coefficient s of Risk of Hazards in Shipwreck Removal Operations in Nigeria's Waterways. The specific objectives of the study are:

- i. To estimate the occurrence probability of individual risk/hazard types associated with shipwreck removal operations in Nigeria
- ii. To rank the risk factors associated with shipwreck removal operations in Nigeria in order of decreasing occurrence probability

1.3 Research Questions

- i. What are the occurrence probabilities of individual risk/hazard types associated with shipwreck removal operations in Nigeria?
- ii. How can the risk factors associated with shipwreck removal operations in Nigeria be ranked in order of decreasing occurrence probability?

2.0 BRIEF REVIEW OF LITERATURE

An investigation on "Shipwreck: A Crisis with Challenging Solutions" was conducted by Ventikos, Koimtzoglou, and Louzi (2014). Among other things, the study's goals were to evaluate shipwreck removal techniques and the risks involved in using each one in order to protect personnel from harm and other dangers related to shipwreck removal operations. To demonstrate the steps involved in shipwreck removal operations and the factors influencing the process's performance, the study used the survey method and case study approach. In order to show which of the most popular procedures is more appropriate for a given situation, Ventikos, Koimtzoglou, and Louzi (2014) present a number of scenarios of the approaches. They also propose ways to mitigate the risks of harm and dangers connected with each technique. They provide an organized framework for the planning phase of such a procedure and generally draw attention to the challenges that arise in shipwreck removal operations.

According to the findings, weather and environmental risks have a significant impact on both the success of a shipwreck removal operation and the strategy chosen. It went on to explain that the marine environment's wave action, wide force, water currents, water resistance, and buoyancy levels significantly impede shipwreck removal operations' progress and may create significant environmental risks and dangers (Ventikos et al., 2014). The study's findings also indicate that the mechanical lifting method of removing shipwrecks is linked to the highest risks of accidents because to its association with fall, vibration, noise, and other hazards.

A research titled "Wreck Removal and the Nairobi Convention a Movement toward a Unified Framework" was conducted by Kern (2016). The purpose of the study was to examine, from a legal standpoint, the obligations of the parties involved in a shipwreck removal operation in accordance with the 2007 Naira Convention on Shipwreck Removal. In order

to investigate the legal obligations of owners and coastal authorities in a shipwreck removal operation as stipulated in the Nairobi Convention on shipwreck removal, the study employed exploratory survey methodologies. The study's conclusions demonstrate that although the 2007 Nairobi Convention on Wreck Removal established the much-needed framework for the removal of shipwrecks from navigable waters, it also grants the coastal state the power to enact regulations to guarantee the prompt and/or efficient removal of shipwrecks from waterways, while also highlighting the fact that the registered owner or owners of the ship are responsible for paying for shipwreck removal expenses. The report therefore states that the registered owners are responsible for removing the wreck or providing funding for the wreck removal operation, but the coastal state should be in charge of identifying the registered owner and the ship's flag state so that communication to remove wrecks will be available. However, because shipwreck removal operations are dangerous, registered owners have avoided conducting a comprehensive impact assessment and identifying the main risks and hazards related to wreck removal operations in an effort to keep costs down over the years. With little to no attention from the coastal state and registered owners, this has resulted in serious workplace injuries for wreck clearance workers and environmental harm to third parties (Kern, 2016).

In a different study titled "Design of a wreck removal method considering safety and economy," Lee (2020) evaluated the methods of choosing shipwreck lifting techniques that will ensure worker and marine environment safety while also providing cost and economic benefits to the registered owner, who bears the responsibility for removing shipwrecks. According to the study, one of the most crucial steps in organizing a salvage operation is deciding on an appropriate lifting technique for wreck removal. To prevent accidents and save time and money, both economy and safety should be taken into account. The study suggested that a key factor in selecting techniques for shipwreck removal operations should be the assessment and confirmation of economy and safety. To evaluate the lifting method's safety, a multi-body dynamics simulation was employed. Specifically, it created a model to compute the contact and friction of the wire when lifting the ship to mimic the wire-wrapping method using primary data and the experimental design methodology. In conclusion, it suggested a way to compare the outcomes of different lifting techniques in order to estimate the overall salvage cost and conduct an economic assessment.

Muhammad (2013) conducted a case study on the Sitakunda shipbreaking industrial region of Bangladesh to examine the health risks and hazards that shipbreaking workers face. Notwithstanding the numerous detrimental effects on coastal environments in Bangladesh's Chittagong region, the study observes that shipbreaking activities face both opportunities and challenges for the holistic management of coastal zones due to the rise in their

demand for raw materials for re-rolling mills and other household uses. The study's goal was to determine the socioeconomic status and health risks of workers in the Sitakunda shipbreaking industrial sector in Bangladesh's Chittagong region as a result of shipbreaking activities. Using a hybrid methodology, the study collected data from primary and secondary sources between September 2012 and August 2013. The socioeconomic status of shipbreaking workers revealed that the majority of them work in hazardous, poorly equipped shipyards where they are susceptible to illnesses and injuries. According to the poll, the majority of the workers were from areas of Bangladesh that were extremely deprived in terms of employment opportunities. According to the report, 40.40% of workers reside continuously in the Chittagong or study region, while 59.59% of workers are migrants from other districts. Five categories serious accident-related hazards, physical hazards, mechanical hazards, biological hazards, and ergonomic and psychological hazards on workers and residents closest to the breaking yards in the study area were found to contain the most common risks and hazards associated with shipbreaking activities (Muhammad, 2013).

A study on "Ship Breaking Industries and their Impacts on the Local People and Environment of Coastal Areas of Bangladesh" was conducted by Kutub, Nishat, Shahreen, and Yasin (2017). According to the study, Bangladesh's coastal regions are among the most environmentally productive and have a rich biodiversity, including a number of endemic species. It was noted that shipbreaking industries in coastal locations have received a lot of attention due to the danger they represent to these vibrant biological communities, their various environmental effects, and the hazardous working conditions for their employees. An exploratory survey design approach was used in the investigation. It was discovered that a number of shipbreaking-related activities, including the discharge of various toxic wastes into the sea, the expansion of shipbreaking yards, the alteration of land-use patterns, and the release of toxic substances into the soil, have seriously contaminated Sitakunda's coastal environment. Additionally, the very hazardous and poisonous working conditions that this industry's employees are subjected to put them at danger for bodily and mental illnesses, as well as unintentional injuries and fatalities. However, labor accept these dangers in exchange for pitiful pay, while the wealthy merchants keep the majority of the earnings. The growing need for raw materials for re-rolling businesses and job prospects for residents of coastal areas have made this industry more significant despite a number of drawbacks (Kutub, Nishat, Shahreen, and Yasin, 2017).

According to Tsaviris (2020), in a different research titled "Wreck removal issues, the contractors' perspective," collisions with sunken shipwrecks that have not been removed over time account for a major portion of the approximately 1000 serious shipping casualties that occur worldwide each year. Most of these wrecks are either pulled to safety or refloated, repaired, and put back into service as a result of successful intervention. About

200 of these cases will be legitimate salvage jobs under various salvage and towage contracts, according to Tsaviris (2020). In certain instances, the intricacy and expense of the repairs and salvage required to return the vessel to service make it unfeasible to do so, and the casualty is deemed a loss. Tsaviris (2020). In some situations, such as when the ship sinks in really deep water, it is completely lost. Although ship owners, insurers, and wreck removal contractors complain that the cost of such operations has skyrocketed in some significant cases, the study acknowledges that removing a vessel's wreckage from the coastline or deeper water has always been a significant and costly undertaking. According to the report, the cost of the impact assessment and the research necessary to determine the extent of the risk factors and dangers connected to the removal job are not even included in the amount being referred to. Tsaviris (2020) reports that the International Group (IG) of major P&I Clubs discovered that the combined cost of the top 20 most costly wreck removals over the previous ten years is currently over US\$ 2.11 billion, and this amount is expected to increase as some cases are still pending. The paper claims that the location of a wreck, local conditions, and the kind of vessel are significant determinants of the cost of the removal process. A remote location could lengthen the operation's duration, requiring more time to charter costly equipment from a distance. Additionally, studies reveal that even small containerships can cause costly mishaps due to the labor-intensive and sluggish process of removing the containers, which is linked to a higher risk of accidents and occupational hazards than bulkers.

The primary goal of wreck removal operations is always to reduce operator exposure to the risks and hazards involved in wreck removal in order to promote safe operations (Tsaviris, 2020). For operators, reducing the effects of exposure to various hazards and hazard categories is equally crucial. According to studies by Bessis (2010) and Hollman (2010), modeling the occurrence probability of the associated risks and hazards and prioritizing the implementation of risk control measures based on the occurrence probability coefficient of each risk/hazard type is the first step towards limiting exposure and impacts of risks and hazards of shipwreck removal operations.

In order to assess and methodically identify, analyze, prioritize, and respond to risks and hazards in shipwreck removal operations, the risks analysis methodology makes use of occurrence probability measurements. Decisions to accept a known or evaluated risk and/or take steps to lessen its effects or likelihood of happening can be made through the risk appraisal process (Tsaviris, 2020). The steps involved are as follows:

- a) **Hazard Identification:** To identify the causes, mechanisms, and incident scenarios, dangers, and hazardous occurrences.

- b) **Consequence Analysis:** To ascertain the magnitude of the repercussions of recognized dangerous incidents.
- c) **Estimating Frequency:** To ascertain how frequently indicated hazardous events occur and what effects they have.
- d) **Risk Summation:** To ascertain the degree of risk.
- e) **Risk assessment:** To determine if a risk is acceptable or unacceptable, to identify strategies for risk mitigation or reduction, and to score these strategies using methods like cost-benefit analysis and risk rating.

There are several different sources of risk and dangers related to wreck clearance operations. Therefore, the occurrence probability measure gives an indicator of the degree of exposure and incidence of each risk or hazard related to shipwreck removal activities in Nigerian waters. As shown in figure 1 below, the assessment's goal is often to move high occurrence probability risks and hazards to low occurrence probability areas that are acceptable and bearable, where exposure to and the effects of such risks and hazards are at their lowest.

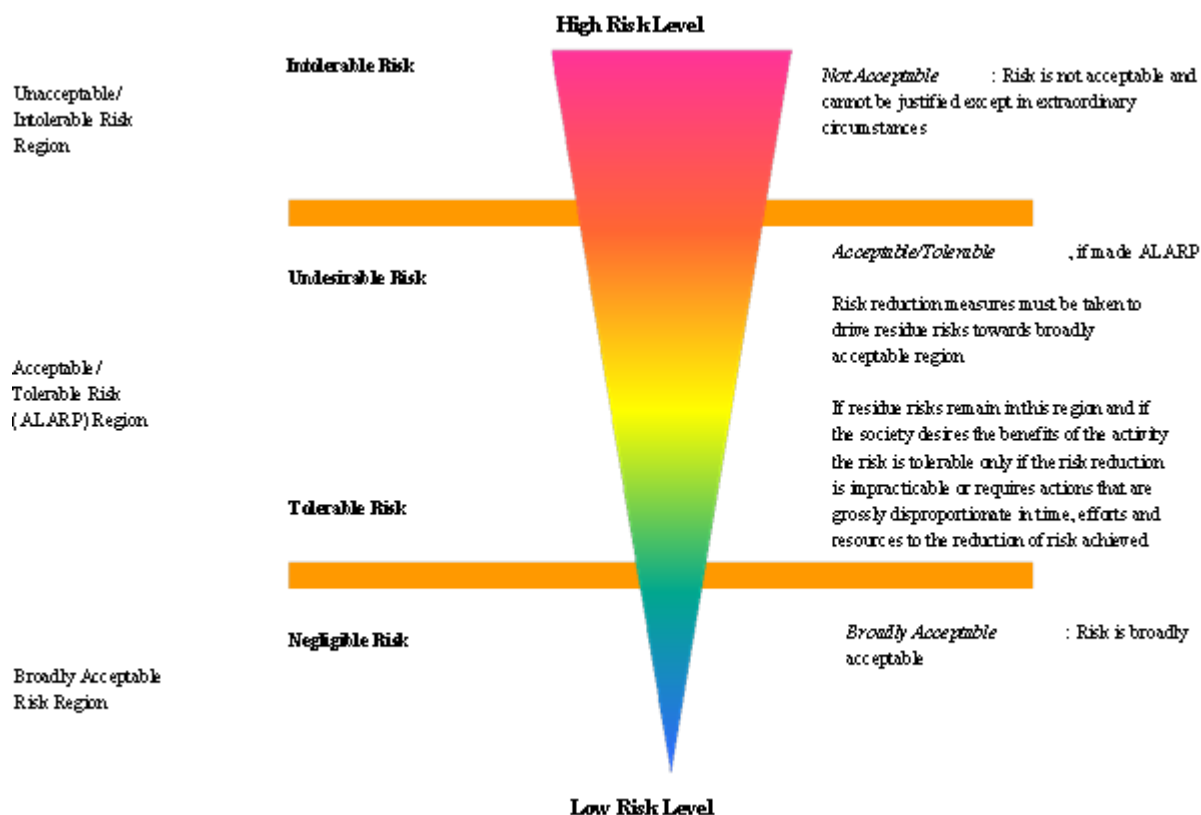


Figure-1: Driving Risk from High Occurrence Probability Regions to Low Occurrence (Risk) Regions.

Source: adapted from IMO 2004; HSE 1999; ISO 1998. **Figure-1: Risk regions/levels and principles of risk tolerability/acceptability and risk evaluation strategies and measures (IMO 2004; HSE 1999; ISO 1998).**

However, there is a knowledge gap that prevents the empirical research that are now accessible from demonstrating which of the identified danger categories and particular hazard types have the lowest chance of occurrence. Over the years, this has made it extremely challenging to assess and prioritize the risks and hazards associated with shipwreck clearance in order to lessen the effects. To create a risk rating framework for the risks connected to shipwreck removal operations in Nigeria, it is crucial to have the occurrence probability, which illustrates the danger or possibility of occurrence of each unique hazard category. However, this information is absent from the empirical literature that is currently

available, which makes it one of the gaps the study discovered and is working to fill.

3.0 DATA AND METHODS

3.1 Description of the Study Area

The research's geographical scope includes the Nigerian maritime environment, specifically the coastal areas and navigation waters in Rivers State and the Niger Delta region. The study's designated area includes the Bonny Channels, the Abonema Port-Harcourt seaport navigable waters, and the Onne-Okrika-Ogu Bollo coastal waters,

which are the seas where the wreck recovery company has operated over the years. In order to examine the likelihood of risks and hazards related to shipwreck removal operations in Nigeria, the study also employed the Bonny Channel Company in Port-Harcourt, Rivers State, as a case study.

3.2 Research Design

Ex-post facto research design was used in the study, and time series secondary data from the company's safety

records from 2012 to 2016 were used. The companies' operations and safety departments provided the secondary data. It included information on how frequently technical risk factors, environmental pollution risk factors, operational risk factors, security risks, and natural risk elements related to shipwreck removal activities occur in their organizations. The following lists the risk factor groupings and the individual risk of hazards taken into consideration:

Table 2: Primary Sources of Risks of Hazards (Risk Factors) Associated with Wreck Removal Operations

s/n	Risk type/grouping	Specific/Individual risk/causes associated with each risk type/group	Associated occupational hazards and effects
1	Technical risks (TR)	i. Hazards related to poor use, inadequacy/lack of requisite equipment and tools (HTE) ii. Hazards related Lack of/poor technical know-how and experience (LTH) iii. Risks related to equipment maintainability problems (REM) iv. Risks related to poor work procedure (RPWP)	i. Occupational Injury to operators ii. Death iii. Environmental damage, etc
2	Natural risks (NR)	i. Hydrological conditions related to underwater and surface water operations in removal of wrecks in the marine environment where wrecks exist (HUSO) ii. Geological conditions and operations (geological operations associated with the digging and excavation of sunken and underwater/submerged wrecks conditions (GESW) iii. Atmospheric weather conditions prevailing in the marine environment to which the operators are exposed induces risk of occupational injury and death that hamper the wreck removal exercise (AWRW)	i. Occupational Injury to operators ii. Death iii. Environmental damage, etc
3	Operational risks (OR)	i. Sudden failure of equipment/downtime (SFE) ii. Human error (HE) iii. Fleet traffic within operating location FTOL) Etc.	i. Occupational Injury to operators ii. Death iii. Environmental damage, etc
4	Security risks (SR)	i. Pirate attacks and kidnap for ransom (PAKR) ii. Attack and Assault on operators (AAO) iii. Deliberate Shooting at and killing of operators (DSKO)	i. Kidnap for ransom ii. Missing of crew iii. Trauma and assault iv. Occupational Injury to operators v. Death, etc.
5	Environmental pollution risk (ER)	i. oil pollution (OP) ii. pollution by noxious chemical substances (PNCS) iii. pollution by other dangerous materials types other than oil and noxious chemicals (PDMT)	i. environmental damage claims by third parties ii. damage to biodiversity iii. Occupational Injury to operators iv. Death, etc

Source: prepared by the author.

The company's occupational safety and health records, which document the history of occurrence of each risk of

hazard related to shipwreck removal operations throughout time, provided the secondary data on the

frequency of occurrence of each risk of hazard kinds. The company's Health, Safety, and Environment (HSE) section also provided records of occupational injuries and fatalities that occurred as a result of operators being exposed to risky conditions during shipwreck clearance operations.

3.3 Data Analysis Technique: Occurrence Probability Theory

Chance or stochastic processes are the subject of probability theory. Based on past data, occurrence probability calculates the chance that an event will occur. Based on past and/or historical data, the occurrence probability coefficient is a numerical value or scores that indicate the possibility that specific events will occur. The likelihood of hazards related to shipwreck clearance operations occurring is a random occurrence. Therefore, the occurrence probability coefficients of each individual risk of hazards in the various groups of risk factors associated with wreck removal operations in Nigerian waters can be estimated using frequency data on individual hazards/risk types in each category of the risk factors in wreck removal operations.

The occurrence probability P_e of an event E is given as:

$$P_e = \frac{F}{N} \text{-----} (1)$$

Where: F = frequency/number of successful occurrences in the past

N = Aggregate frequencies representing number of possible outcomes.

P_e = occurrence probability coefficient showing the likelihood of occurrence of event 'e'.

The categories of risk factors associated with wreck removal operation as aforementioned include TR, NR, OR, SR, and ER.

Technical risk factors (TR) have individual risk/hazard components which include:

- i. Hazards related to poor use, inadequacy/lack of requisite equipment and tools (HTE)
- ii. Hazards related Lack of/poor technical know-how and experience (LTH)
- iii. Risks related to equipment maintainability problems (REM)
- iv. Risks related to poor work procedure (RPWP)

The occurrence probability P_e of each of the individual technical risk/hazard types for example is given as:

$$P_{eHTE} = \frac{HTE}{TR} \text{-----} (2)$$

Where: HTE = frequency of occurrence of risk of hazards associated poor use and inadequacy of equipment and tools over the years.

TR = aggregate total occurrence of technical risks recorded over the period.

The occurrence probability coefficients of the remaining individual technical risk types are shown respectively below.

For the risks/hazards related to poor technical know-how and inexperience, the occurrence probability

$$P_{eLTH} = \frac{LTH}{TR} \text{-----} (5)$$

For risks of hazards related to equipment maintainability issues (REM), we have:

$$P_{eREM} = \frac{REM}{TR} \text{-----} (3)$$

For risk of hazards related to poor work procedure, we have

$$P_{eRPWP} = \frac{RPWP}{TR} \text{-----} (7)$$

It is important to state that by the rules of probability theory:

$$\sum P_{eHTE} + P_{eLTH} + P_{eREM} + P_{eRPWP} = 1$$

Similarly, the occurrence probability coefficients of the individual components of the risk of hazards in each of the Operational risk factor (OR), natural Risk factors (NR), Security Risk factors (SR) and Environmental Risk factor (ER) will determined using the occurrence probability analytical tool discussed earlier. Using the methods discussed above, the study analyzed the data obtained in order to provide answers to the research questions.

4.0 RESULTS AND DISCUSSION OF FINDINGS

4.0 Data Presentation

Table-4.1: Occurrence frequency of individual hazards risks associated with wreck removal operations in Rivers Coastal zones of Nigeria between 2012 and 2016.

s/n	Type/Category of Risk/Hazard	Occurrence Frequency of individual risk/hazard types					Total
1	Technical Risks	Risks/hazards:	HTE	LTH	REM	RPWP	
		Frequency:	7	9	2	6	24
2	Natural risks	Risks/hazards:	HUSO	GESW	AWRW	-	
		Frequency:	6	8	3	-	17
3	Operational risks	Risks/hazards:	SFE	HE	FTOL	-	
		Frequency:	8	16	3	-	27
4	Security risks	Risks/hazards:	PAKR	AAO	DSKO	-	
		Frequency:	11	2	1		13
5	Environmental pollution risks	Risks/hazards:	OP	PNCS	PDMT	-	
		Frequency:	12	5	4	-	21

Source: Secondary Data Sourced from the HSE Records of the Company.

Table-4.1 above shows the occurrence frequency of the various categories of risk of hazards associated with shipwreck removal operations in Rivers and Bayelsa waters between 2012 and 2016. The data was obtained from the HSE records department of the company. It also indicates the individual risks classified under technical risk, natural risk, operational risk, security risk and environmental risk categories that the organization experienced/faced over the years in various wreck removal operations it carried out. The table-4.2 indicates that the company faced a total of 24 incidents classified under technical risks associated with shipwreck removal operations over the period. Of these 24 incidents, 7 incidents are hazards related to poor use, inadequacy/lack of requisite equipment and tools (HTE). 9 incidents are hazards related to lack of/poor technical know-how and experience (LTH); hazards related equipment maintainability problems (REM) and poor work procedures (RPWP) have 2 and 6 incidents respectively.

About 17 incidents are linked to hazards categorized under Natural risk. Under the natural risks, hazards related hydrological conditions of the underwater and surface water in the coastal zones

(HUSO) has occurrence frequency of 6 while the number of incidents associated with geological conditions in the digging of submerged wrecks (GESW) is 8. The frequency of incidents related to atmospheric hazards (AWRW) is over the period is 3. Operational risk, security risk and environmental pollution risk have respectively occurrence frequencies of 27, 13 and 21 respectively, over the period.

The frequency of occurrence of incidents related to human error, sudden failure of equipment and downtime (SFE), and fleet traffic level/condition with the operational zone (FTOL) is 16, 8, and 3 respectively. Under the security risk category, frequency of incidents of kidnapping operational staff of the company for ransom (PAKR), attack and assault on wreck removal operators (AAO) and deliberate shooting at and killing of operators (DSKO) is 11, 2 and 1 respectively. Under the environmental risk category, the risk and hazards of oil pollution (OP), pollution by noxious chemical substances (PNCS), and pollution by other dangerous materials (PDMT) is 12, 5 and 4 incidents respectively. The above secondary data was employed in providing answers to the research questions in subsequent sections of the study.

Table-4.2: Occurrence probability coefficients of individual risks of hazards affecting shipwreck removal operation in Nigeria

s/n	Type/Category of Risk/Hazard	Occurrence probability coefficient(s) of individual risk/hazard types					aggregate
1	Technical Risks	Risks/hazards:	HTE	LTH	REM	RPWP	
		Probability coefficient:	0.29	0.38	0.08	0.25	1.0
2	Natural risks	Risks/hazards:	HUSO	GESW	AWRW	-	
		Probability coefficient:	0.35	0.45	0.17	-	1.0
3	Operational risks	Risks/hazards:	SFE	HE	FTOL	-	
		Probability coefficient:	0.30	0.59	0.11	-	1.0
4	Security risks	Risks/hazards:	PAKR	AAO	DSKO	-	
		Probability coefficient:	0.85	0.15	0.07	-	1.0
5	Environmental pollution risks	Risks/hazards:	OP	PNCS	PDMT	-	
		Probability coefficient:	0.57	0.23	0.19	-	1.0

Source: author's calculation

The result on table-4.2 shows the occurrence probability coefficient of the individual risks of hazards grouped under each of the four categories of risk associated with shipwreck removal operations in Nigeria's waters. The result indicates that of the four individual risks of hazards grouped under technical risks which include: inadequate/lack of requisite equipment and tools (HTE), hazards related to lack of/poor technical know-how and experience (LTH), hazards related to equipment maintainability problems (REM) and poor work procedures (RPWP) have respective occurrence probability coefficients of 0.29, 0.38, 0.08 and 0.25. This indicates that while hazards related to lack/poor technical know-how and experience (LTH) has the highest occurrence probability coefficient of 0.38, risk of hazards related to equipment maintainability problems has the

least occurrence probability coefficient of 0.08. The implication is that for technical hazards, risk of hazards related to poor technical know-how and inexperience (LTH) possess the greatest likelihood/probability of occurrence in shipwreck removal operations and as a result has the greater chance of marring the success of the shipwreck removal operation than any other technical risk/hazard. This is followed by the likelihood of occurrence of inadequacy and improper use of equipment and tools (HTE) and hazards related to poor and improper work procedures (RPWP). Figure-4.2 below shows the ranking of the risk of hazards under the technical risks category in decreasing order of likelihood/probability of occurrence in shipwreck removal operations in Nigeria's waterways.

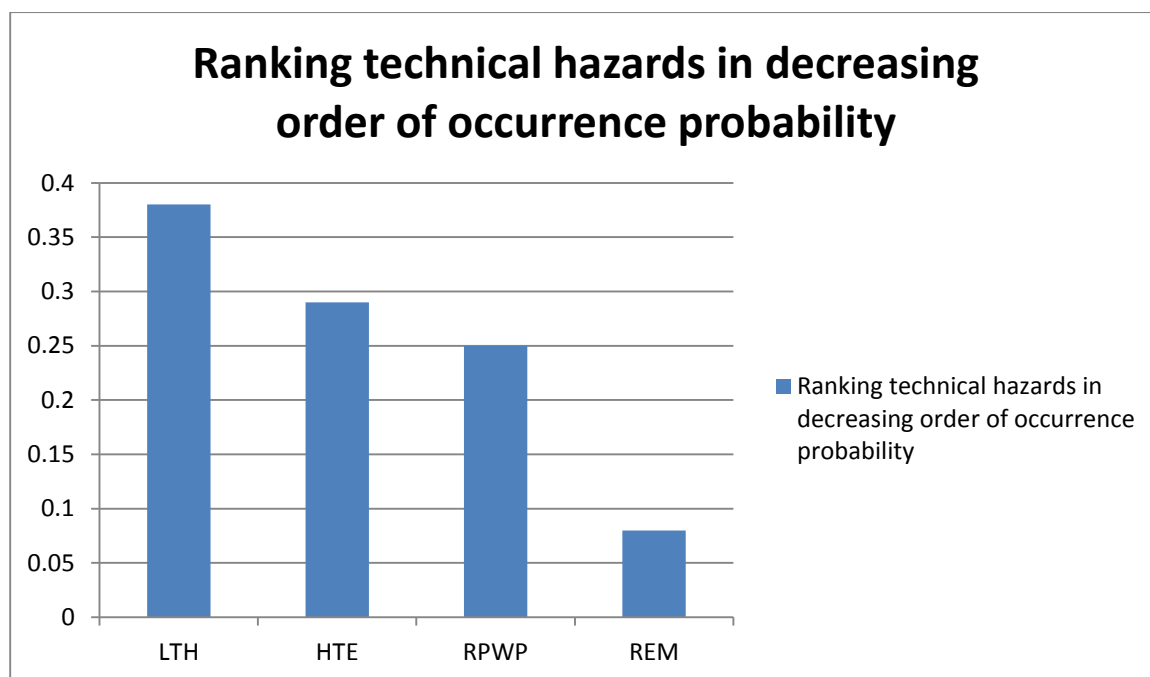


Figure.2: Ranking technical hazards in decreasing order of occurrence probability

Under the natural risk (NR) category, risk of hazards related to the hydrological conditions of the under and surface waters in the zone (HUSO), hazards related to the geological conditions associated with excavation/digging of submerged wrecks (GESW), and hazards related to atmospheric conditions in waters (AWRW) have respective occurrence probability coefficients of 0.35, 0.45 and 0.17. This implies that hazards associated with geological conditions in the excavation of wrecks have the highest occurrence probability coefficient of 0.45 followed by hydrological risks with probability coefficient of 0.35. Atmospheric

hazards have least probability coefficient of 0.17. By implication, the natural risk with the most likelihood of occurrence in a shipwreck removal operation is geological risks/hazards, followed by hydrological risks/hazards. When considering the reduction of the effects of natural risks on shipwreck removal operations therefore, the priority should be placed on eliminating geological hazards followed by hydrological hazards before atmospheric hazards. Figure-4.3 below shows the presentation of the occurrence probability coefficients of natural risks in decreasing order of influence.

Ranking natural hazards in decreasing order of occurrence probability



Figure-3: Ranking natural hazards in decreasing order of occurrence probability

Under the operational risk category, risk of hazard of sudden failure of equipment (SFE), human error (HE) and fleet traffic level/condition operational in the zone (FTOL) have respective occurrence probability coefficients of 0.30, 0.59 and 0.11. The indication is that human error has the highest probability of occurrence and constitute the operational hazards that disrupt most

the success of shipwreck removal operations in Nigeria's waters. This is followed by sudden failure of equipment (SFE) with probability coefficient and likelihood of occurrence of 0.30. Figure-4.3 below is a pie chart showing the degrees of negative influences of the individual risk of hazards classified as operational risks in shipwreck removal operations in Nigeria waters.

Ranking operational risk in decreasing order of occurrence probability

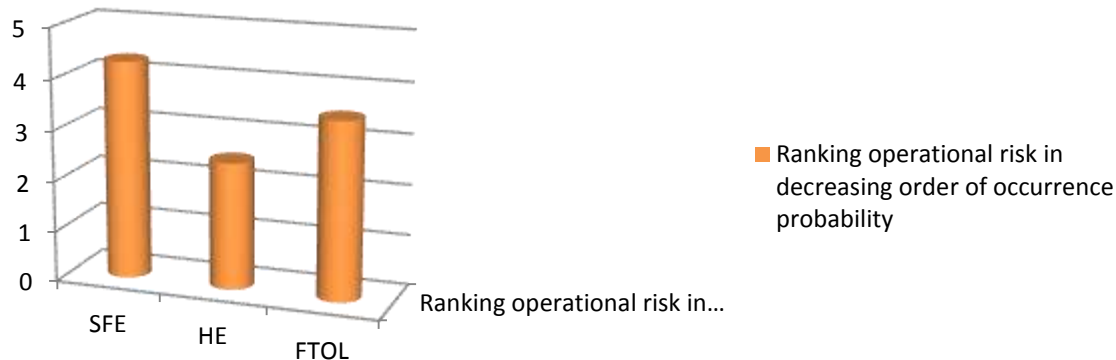


Figure-4: Ranking operational hazards in decreasing order of occurrence probability

Under the security risk category, the occurrence probability coefficient of risk of kidnapping operational staff of the company for ransom (PAKR) is 0.85, probability coefficient of attack and assault on wreck removal operators (AAO) is 0.15, and the probability coefficient of deliberate shooting at and killing of operators (DSKO) is 0.07. This implies that kidnapping the company's operational staff for ransom possesses the greatest probability coefficient and likelihood of occurrence. It thus constitutes the security risk with the most potential of disrupting shipwreck removal operations in Nigeria waters.

Similarly, for risk of environmental pollutions, hazards related to risk of oil pollution (OP) in the course of shipwreck removal has the highest probability coefficient of 0.57 followed by the hazards of pollution by

noxious chemical substances (PNCS) with probability coefficient of 0.23. The hazards related to risk of pollution by other dangerous materials other than noxious chemicals and oil (PDMT) has the least probability coefficient and likelihood of occurrence of 0.19. This indicates that oil pollution risks/hazards has the highest likelihood of occurrence and as a result constitute the most environmental risk/hazards associated with shipwreck removal operation in Nigeria waters. Figure-4.4 below shows the pie chart indicating the degrees of likelihood of occurrences of the individual environmental risks/hazards identified. Shipwreck removal operations should thus prioritize the elimination of the risks with the greatest likelihood of occurrence as they constitute the greatest threats to successful shipwreck removal operations in Nigeria's waterways.

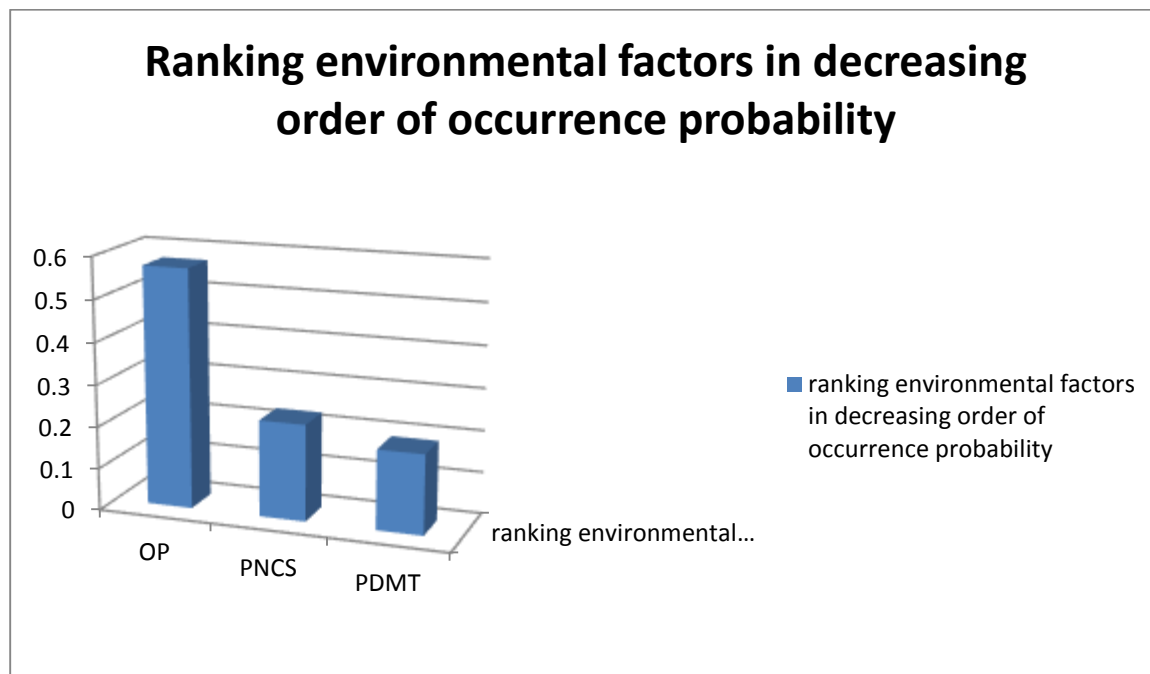


Figure-5: Ranking environmental hazards in decreasing order of occurrence probability

Table- 4.3: Occurrence probability coefficient of the categories of risk factors between 2012 and 2016

Risk factor	TR	NR	OR	SR	EN	aggregate
Occurrence probability coefficient(s)	0.23	0.16	0.27	0.13	0.21	1.0

Source: author's calculation

Table 4.3 shows that the occurrence probability coefficient of technical risk (TR) over the period covered in the study is 0.23 while the occurrence probability coefficient of natural risk (NR), operational risk (OR), security risk (SR) and environmental risk over the period is 0.16, 0.27, 0.13 and 0.21 respectively. This implies that operational risks with probability coefficient of 0.27 have the highest probability coefficient a likely of occurrence to the disadvantage of the successful conclusion of shipwreck removal operations in Nigeria. Technical risk

follows second in disrupting the success of shipwreck removal operations with a likelihood of occurrence score of 0.23 while environmental risk follows with likelihood of occurrence score 0.21. Natural risk and security risk have least disruptive effects on the success of shipwreck removal operations with likelihood scores of 0.16 and 0.13 respectively. The implication is that shipwreck removal contractors and companies in Nigeria should prioritize the reduction, control and elimination of the categories of risks with the highest probability

coefficients and likelihood of occurrence. The result indicates that technical risks of hazards has about 23% occurrence probability while natural risk, operational risk, security risk and environmental risks have occurrence

probabilities of 16%, 27%, 13% and 21% respectively in shipwreck removal operations in Nigeria maritime industry.

Table-4.4.: Ranking the individual risks/hazards associated with shipwreck removal operations in order of decreasing occurrence probability

Risk factor/hazard type(s)	Occurrence likelihood probability%	Rank (s)
Operational risks/hazards (OR)	27%	1
Technical risks/hazards (TR)	23%	2
Environmental risks/hazards (EN)	21%	3
Natural risk (NR)	16%	4
Security risks (SE)	13%	5

Source: authors' calculation

The ranking indicates that operational hazard types which include Sudden failure of equipment/downtime (SFE), Human error (HE), Fleet traffic within operating location FTOL), etc have the highest occurrence probability of 27% followed by technical risk/hazards types which include Hazards related to poor use, inadequacy/lack of requisite equipment and tools (HTE), Hazards related lack of/poor technical know-how and experience (LTH), Risks related to equipment maintainability problems (REM), and Risks related to poor work procedure (RPWP) with occurrence probability of 23%. Risk of Environmental hazards is third in the ranking with occurrence probability of 21%, followed by natural and security risks types.

5.0 CONCLUSION

According to the study's findings, burn injuries are the most common kind of injuries sustained by wreck removal workers as a result of welding and cutting risks. Following this, roughly three workers were impacted over time by cuts, bruises, and arc eye injuries. During the study period, only two wreck workers experienced musculoskeletal injuries, fractures, laceration injuries, and strains and sprains. Similarly, the second-highest number of illnesses and injuries among accident workers during that time period were brought on by exposure to dust and chemical fumes from sandblasting and painting procedures. Rhino rhea and eye irritation are the two main ailments brought on by this hazard category, affecting three and two wreck workers, respectively, over time.

Two dockworkers experienced tinnitus as a result of exposure to noise dangers in the shipyard, while two wreck workers experienced headaches as a result of exposure to vibration hazards. The study's findings make it clear that over half of the health risks experienced by wreck workers in Nigerian wreck removal operations were related to welding and cutting hazards.

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