Measuring The Probabilities Of Fatal And Non-Fatal Accident Risks In Upstream Ocean-Energy Drilling Operations In Nigeria

Nwokedi, Theophilus Chinonyerem
(Email: Department of Maritime Management Technology ,Federal University of Technology, Owerri Nigeria
Email: nwokeditc@gmail.com)

Odumodu, Chigozie Uzoma,
Graduate School, University of Strathclyde, 16 Richmond Street Glasgow G1 1XQ, UK

Gbasibo, Lawrence Addah
Maritime Management Technology, Federal University of Technology, Owerri

Ibe, Callistus Chukwudi
Department of Transport Management Technology, Federal University of Technology, Owerri, Nigeria

Anyanwu, Chibuzor Ebere
Department Maritime Transport and Business Studies, Maritime Academy of Nigeria, Oron Nigeria

Okonko, Ifiokobong I.
Maritime Management Technology,
Federal University of Technology, Owerri Nigeria

***Abstract*—The study was carried out to analyze the safety and accident risks in offshore energy drilling operations with a view to determining the empirical probabilities of fatal and non-fatal upstream accidents in the oil and gas sector of Nigeria. The objectives of the study were among other things to determine the empirical probabilities of fatal and non-fatal offshore energy drilling accidents and compare the probabilities for significance in difference. The study used a historical and investigative design method in which time series ocean energy drilling accidents were collected through secondary sources and investigated using scientific and statistical tools including probability theory and independent sample t-test statistical tools. It was found that though the average empirical probability coefficient of non-fatal upstream accident over the period covered in the study was higher, there exists no significant difference in the empirical probabilities of fatal and non-fatal offshore energy drilling accidents in Nigeria. Recommendations were proffered based on the research findings.**

Keywords—fatal, non-fatal, upstream, ocean-energy-drilling, accidents.

1. Introduction

Risk as a concept is defined as the probability that an event may occur that will affect the outcome of an objective function. Relative of ocean energy drilling operations, it is the uncertainty that an offshore exploration or drilling project may face a sudden unexpected incident/accident that may affect adversely the achievement of the objectives of the project [1]. This non achievement of the objective function may be termed failure depending on the extent of non-achievement. Thus risks are uncertainties which cause projects and programme to suffer failure. Accident risks may impose damages, injuries and death in which case they are categorized as either damage accident, injury accident and/or death accidents with each accident categories having differing methods and models of determining their economic and socio-environmental impacts Nwokedi etal[2]. According to [2][3], when accidents involve death of crew and/or personnel, it is termed fatal accidents while non-fatal accidents do not involve the dead of crew or personal but may involve injuries. The development of offshore safety policies and programmes and international maritime safety conventions relating to ocean energy exploration and drilling are all aimed at ensuring the safety of personnel, environment and equipment as capitals for realization of the ocean drilling objectives and the sustenance. But since the human capital remain the driving factor and reference force that propels and harnesses all the factor of production in the offshore energy sector, higher accident fatality rate and probability of fatal offshore drilling accident will without doubt obstruct the realization and success of ocean energy drilling operations. Considering the capital intensiveness of safety and specialized training needs for human operators in the ocean energy sector; the loss imposed by fatal offshore energy drilling operations is usually enormous. Where this is the case, cost offshore ocean energy insurance and risk management measures may equally go up inducing limitations of investment in the sector since the higher risk and may push up investment costs such that investors are discouraged [1]. This will in turn affect limit job creation drives while increasing unemployment with series of other related social and environment challenges. As aforementioned, failure of oil drilling operations on platforms and Floating production, Storage and Offloading (FPSO) systems may lead to injury risks, economic risks, death, risk of environmental pollution among others; the failure of the drilling infrastructure itself is an occurrence that is a factor of risk as a result of exposure to various forms of hazards which represent casual agents of failures or failure modes [1, 4].

Though it is important to work to limit the occurrence of accident of any form whether fatal or non-fatal, but since offshore drilling operations are accident prone given the nature of the environment and it may not be possible to achieve a totally accident free operation, it is a better option to while working the limit accident occurrence generally, focus on determining the probabilities of fatal and non-fatal accident involving offshore drilling sector over a period with a view to putting higher concentration on reducing fatal accidents to the barest. Abednego [5] posits that while accidents may not be possibly eliminated, fatal accident can be completely eliminated through proactive accident and safety management system, and when fatal accidents are completely eliminated; the objective function the offshore drilling operations will be achieved. The implication of this is the human capital loss induced on the company, industry, and economy by fatal accidents will be eliminated too. The economic benefits of implementing fatal accident risk management and control methods when compared the cost imposed by fatal accident in the short run may prove favourable for fatal accident control mesures coupled with the fact that human life itself unlike other forms of capital is irreplaceable there exists an infinite loss of output for every human capital accident induced death. When properties involved in damage accident can be overhauled, repaired and maintained and put back into productive, the same cannot be said of human capitals involved in fatal accidents, thus the need for the study to proactively determine the fatal accidents probabilities in FPSo's in use in ocean energy drilling operations in Nigeria in comparison to non-fatal accident probabilities in the drive to limit human capital losses induced by offshore energy drilling operations and the associated socio-economic multiplier effects. The International Maritime Organization [1] developed the Formal safety Assessment (FSA) method in risk analysis in offshore drilling platforms and operations in the global ocean energy sector. Osuji [6] and Olumide [7] note that the offshore energy sector is the oil and gas sector, encompassing the oil and gas exploration and drilling operations using offshore oil and gas installations which in the most simplest form consists of exploration vessels, seismic equipment, FPSO's, shuttle tankers, dynamic positioning (DP) vessels, and the associated deep water pipeline transport infrastructure for drilling, transfer and storage of petroleum and gas resources. Statistics from NAPIMS [4] indicates that Nigeria has about 500 oil fields each employing various categories and capacities of drilling equipment for operation. Global project management and safety management practices require that the risk potentials and failures causing deaths and environmental pollution of each drilling platform/rig be identified, analyzed and assessed to determine the level of fatality, injury and environment risks; and appropriate risk control strategies be applied to limit accidental failures and the unpleasant consequences. A typical case with serious fatality in Nigeria in recent time is the case of the 'JASON 4' where the oil service tugboat drowned off the coast of Nigeria killing 10 of the 11 crew members onboard in 2014.

2. Objectives

The main objective of the study is to analyze the fatal and non-fatal accident risks i offshore energy drilling operations in Nigeria in order to determine the empirical probabilities functions of each upstream energy drilling accident outcome groups between 2010 and 2017 and the measure the significance of the difference if any between the probabilities of fatal and non-fatal upstream energy drilling operations in Nigeria over the period.

2.1 Brief Review of Literature

According to the U.S. National Institute for Occupational Safety and Health in International Oil and Gas producers (IOGP) Report [8], a worker in the oil and gas industry is six times more likely to die on the job than the average American worker. The IOGP [8] report notes that when workers are offshore, help is not close by, as a result of which an incident such as a mirror fire outbreak or another incident may quickly escalate into a tragedy with high fatality. For example, the Deepwater Horizon in the Gulf of Mexico in 2010 accident which claimed the lives of about 200 workers who perished in explosions and the Piper Alpha in the North Sea in 1988 in which 167 oil workers perished with only 61 survivals who jumped into the sea from the helicopter deck of the drilling rig gives an indication of the fatal and perilous nature of most ocean energy drilling accidents IOGP [8]. According IOGP [8], most work-related injuries and fatalities are associated with working in an extremely high-pressure and physically demanding environment. Since upstream oil field jobs involves working on heights, heavy equipment, challenges getting to and from job sites and hazardous and dangerous materials, The probability of fatal accidents is usually very high.

The U.S. Center for Disease Control (USCDC) [9] report indicates that oilfield work often appears on lists of the most dangerous professions. As the oil and gas industry boomed from an average of 800 active drilling rigs in the 1990s to approximately 1,300 in the time period from 2003 to 2006, the worker fatality rate increased, with over 400 workers losing their lives on the job. The U.S. Center for Disease Control found that the annual fatality rate climbed to 30.5 per 100,000 workers over those four years alone [9]. The three states with the most oilfield deaths in the United

States of America in 2008 were Texas, Oklahoma and Louisiana. From 2004 until 2008, the number of fatalities while working in the upstream oil and gas industry increased by 91 percent in Oklahoma, 21 percent in Texas and 30 percent in Louisiana [9]. IOGP [8] notes that in addition to an alarming high worker death rate in the oil and gas industry, life-altering injuries can also occur. In 2016 alone, at least 20 workers a month were hospitalized or lost a body part while on the job. Oilfield workers can also experience major burns and fractures, among other injuries. The Labor Department speculates that employers under report injuries by as much as 60 percent. The former head of the Occupational Health and Safety Administration (OSHA) pointed out that a culture of not reporting these incidents in the oil and gas industry is common, so even more workers are probably hurt or injured on the job [8]. [5] in a study found that that the fatal explosion in the pump room on the Brazilian FPSO Cidade de São Mateus in February 2015, demonstrated the potential for major accidents on this type of unit[5]. It is therefore imperative that risk assessments of FPSOs address this type of event [5].

3. Materials and Method

This study used a historical survey method in which time series data on upstream energy drilling accidents in the oil and gas sector of Nigeria involving oil and gas drilling platforms and FPSO's were collected from the Nigerian oil and Gas report [4] edition. The time series data covered a period of 8 years from 2010 to 2017 on upstream fatal and non-fatal accidents involving drilling platforms. The data were thus analyzed using the methods of statistical and empirical probabilities.

3.1 Empirical probability measure

Probability theory deals with chance or stochastic process also referred to as a random process. Probability is a numerical value that measures the uncertainty that some events will occur based on the current operations. It anticipates uncertainty in the future business outlook Kallenberg [10]. Upstream accident risks are occurrences based on chance (stochastic), the fatal and non-fatal offshore drilling accident types are both mutually exclusive and disjoint event. Probability theory states:

P (successful outcome) = number of successful outcomes/ Number of possible outcomes (i)

This is the same for the probability of unsuccessful outcomes.

Thus for offshore drilling accidents per annum, probability that an offshore drilling accident will be fatal is:

P(Ft) = number of successful fatal accidents/Number of possible outcomes (ii)

Where F = fatal upstream drilling accident.

Kallenberg [11] posits that a sample space (S) is a set of logically possible outcomes resulting from the trial experiment. Sample space (S) is formed by Sample points which represent all possible outcomes of the trial. For example in tossing a coin, the possible outcomes are a head (H) and a tail (T). Therefore, the two (2) sample points (possible outcomes) of H and T from the set of a sample space in tossing a coin such that;

$S = \{H, T\}$.

Similarly, a single oil drilling accident in Nigeria presents possible consequences (outcomes) of fatal (Ft) and non-fatal (Fn).

Thus the sample space for a single incident of upstream energy drilling accident risk is represented by the set formed by the sample points as:

$S = \{Ff, Fn\}$. (iii)

The probability theory states that an event is simply a subset of the sample space S.

Thus the sample space presented by ocean energy drilling operations accident risk is such that:

Ft, C Fn, ie fatal upstream accident risks is a subset of non-fatal upstream accident risk.

Where C = sub-set notation, S = sample space, Ft = fatal offshore drilling accident Fn = non-fatal accident.

Using the equally likely or theoretical probability measure based on the above, we assign the same probability P (si) = 1/N to each upstream accident outcome types.

Thus the equally likely probability for 1/2; ie, it is either the ocean energy drilling accident is fatal or it is non-fatal and theoretical probability measure assume fair chances for both = ½.

The Empirical probability function measures for each of fatal and non-fatal offshore drilling accident outcomes can be computed by using the 8 years' time series by employing equation;

$F'(Ft) = F(Ft)/N$ (iii)

For non-fatal = $F'(Fn) = F(Fn)/N$ (iv)

Using the methods discussed above, the research analyzed the data obtained using the basic rules of probability and the derived equations. The independent sample t-test was used to compare the fatal and non-fatal ocean energy drilling accident risks in Nigeria.

3.: Results and Discussion

3.1: Empirical Probability Fatal And Non-Fatal Accident Risks In Upstream Energy Drilling Operations

Incident dates	Empirical prob. Of fatal accidents	Empirical probability of non-fatal accident
2010	0.42	0.59
2011	0.39	0.61
2012	0.54	0.46
2013	0.36	0.64
2014	0.41	0.59
2015	0.66	0.34
2016	0.46	0.55
2017	0.43	0.56
Average	0.45	0.55

Source: Authors calculation.

The result of the analysis indicates that over the 8 years period covered in the study, the coefficient of the average empirical probability function of fatal and non-fatal upstream accident risks are 0.45 and 0.55 respectively. The sum of the average probabilities is (0.45 +0.55 =1) is one which indicates the non-violation of the probability rule that the sum of probabilities of a sample. The implication is that the risk/probability of occurrence of non-fatal accidents in upstream drilling operations is greater than (ie: 0.55 > 0.45) than the risk of occurrence of fatal accidents. Thus upstream energy drilling operations has average probability of fatality of 0.45 as against the average probability of non-fatality of 0.55. A comparison of the empirical probabilities of occurrence is important in order to determine the significance of this difference in the fatality and non-fatality risks of ocean energy drilling operations in Nigeria. Similarly, the empirical probabilities of non-fatal upstream accidents in each year covered in the study is higher than the empirical probabilities of fatal accidents except in the years 2012 and 2015 when the empirical probability coefficients of fatal accidents where higher reaching maximum values of 0.54 and 0.66 respectively in 2012 and 2015 against non-fatal probability values of 0.46 and 0.34 respectively in the same years.

Table3.2: Trend of Upstream/offshore accidents on Drilling Platforms

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	68.149	1	68.149	2.314	.179[b]
	Residual	176.726	6	29.454		
	Total	244.875	7			

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	45.607	4.229		10.785	.000
	Time	-1.274	.837	-.528	-1.521	.179

Residuals Statistics[a]

	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	35.4167	44.3333	39.8750	3.12018	8
Residual	-7.23810	6.21429	.00000	5.02460	8
Std. Predicted Value	-1.429	1.429	.000	1.000	8
Std. Residual	-1.334	1.145	.000	.926	8

a. Dependent Variable: Upstreamaccidents

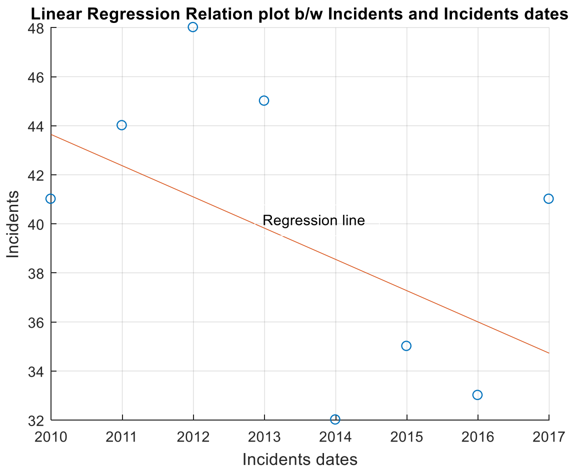
Source: Authors Calculation.

The result of the analysis indicates that a total of 319 accidents occurred on upstream drilling operations in Nigeria over the period covered in the study from 2010 to 2017. This indicates a mean annual occurrence of 39.9 or approximately 40 upstream drilling accidents in each year covered by the study with a standard deviation of 3.12018. The average numbers of fatal and non-fatal incidents 18.1 and 21.8 respectively. The coefficient of the explanatory variable is -1.274 indicating a decreasing trend in upstream oil and gas drilling accidents in Nigeria. The equation or model showing the trend of upstream drilling accidents over the period covered in the study is:

$$Y = 45.607 - 1.274X + e.$$

As earlier stated, this indicates a decreasing trend in offshore drilling accidents. A t-score of -1.521 and p-value of 0.179 however shows that the trend is not significantly decreasing. The probability plots or chart showing the decreasing trend in upstream drilling operations is shown below:

Figure 5: The Trend plot of Upstream Energy Drilling Accidents in Nigeria.



Source: Authors Calculation

3.3 Comparing the Empirical Probabilities of Fatal And Non-Fatal Accidents

Independent Samples Statistics

	Mean	N	Std. Deviation	Std. Error Mean
probfatal	.4578	9	.09107	.03036
probnonfatal	.5433	9	.09138	.03046

Paired Samples Correlations

	N	Correlation	Sig.
probfatal & probnonfatal	9	-.998	.000

Independent Samples Test

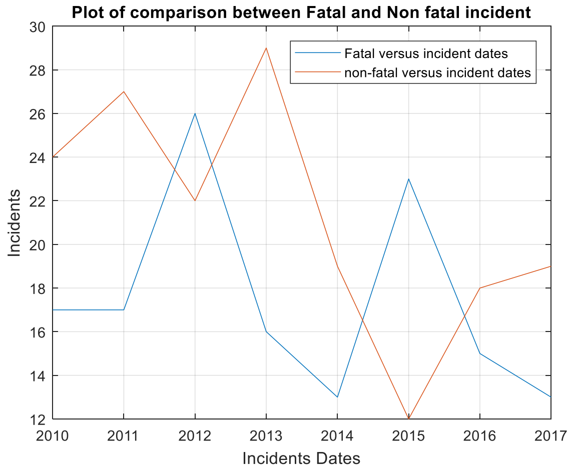
	Differences			
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference
				Lower
probfatal - probnonfatal	-.08556	.18235	.06078	-.22572

Samples Test

	Paired Differences	t	df	Sig. (2-tailed)
	95% Confidence Interval of the Difference			
	Upper			
probfatal - probnonfatal	.05461	-1.408	8	.197

Source: Authors calculation.

The result shows the comparison of the empirical probabilities of fatal and non-fatal accidents in upstream drilling operations using independent sample t-test. The indicates a mean fatal empirical probability coefficient of 0.46 and a standard deviation of 0.091 against a mean non-fatal accident coefficient of empirical probability of 0.54 with a standard deviation of 0.091 showing a mean difference of -0.08556 in favour of non-fatal accident empirical probability with a standard deviation of 0.18235. The t-score of -1.408against a t-table of 1.83 and a p-value of 0.197 shows that there are no significant difference between the probabilities of fatal and non-fatal accident risk in upstream drilling operations. We may thus assert that there exist equal chances (likelihood) of fatality and non-fatality in accident risks involving upstream drilling platforms in Nigeria. A plot of the comparison of probabilities is as shown below:



The plots in both incidents do not depict a linear relationship between them and dates of their incidence.

4. Conclusion

Over the period covered in the study**,** the mean annual upstream drilling accident occurrence of 39.9 or approximately 40 was recorded in each year covered by the study with a standard deviation of 3.12018. The average numbers of fatal and non-fatal incidents 18.1 and 21.8 respectively. The coefficient of the explanatory variable is -1.274 indicating that there is a decreasing trend in upstream oil and gas drilling accidents in Nigeria. The equation or model showing the trend of upstream drilling accidents over the period covered in the study is: $Y = 45.607 - 1.274X + e$. Over the 8 years period covered in the study, the coefficient of the empirical probability function of fatal and non-fatal upstream accident risks are 0.45 and 0.55 respectively. The sum of the probabilities is (0.45 +0.55) is one which indicates the non-violation of the probability rule that the sum of probabilities of a sample must be equal to or 1 and not greater. The implication is that the probability that an upstream drill accident if occurred will be a non-fatal accident is greater, thus the chances of having a non-fatal upstream accident is greater than the chances of a fatal accident. There are no significant differences between the probabilities of fatal and non-fatal accident risk in upstream drilling operations. There exist on the average equal chances (likelihood) of fatality and non-fatality in accident risks involving upstream drilling platforms in Nigeria given that a significant difference does not exist between the empirical probabilities.

5. Recommendation

It is recommended that upstream operators should develop strategies to eliminate or reduce the occurrence of fatal accidents in offshore drilling operations since the existence of almost equal likelihood of fatality and non-fatality raises serious concerns regarding the safety of human resources employed in the offshore ocean energy drilling sector.

References

[1]IMO (2008) International safety management (ISM) code 2002 Available at http//www.IMO.org/Human element/maritime organization. Accessed Sept. 8, 2017.

[2] Nwokedi T. C., Ibe C.; Okeudo G., Moses N. (2017) Analysis of Vessel-Based Marine Accidents and the Economic Risks to Nigeria. Journal of Water Resources and Ocean Science 2017; 6(6): 72-84. doi: 10.11648/j.wros.20170606.11.

[3] Nwokedi T.C., OKAFOR C.; NWAOSU E.N.; CHINYEAKA N. N.; GBASIBO L. A. & OKEKE, K.O. (2018) An Appraisal Of Maritime Safety Management Practices And Organizational Safety Performance In Nigeria Maritime Domain: The Case Of Bourbon Interoil Nigeria Limited. International Journal of Engineering Technology and Scientific Innovation 2018, 3(4) 188 – 200. doi.org/10.5281/zenodo.2527946.

[4] NAPIMS (2014). The National Petroleum Investment Management Services (NAPIMS); 2014 Annual Reports.

[5] Abednego A.,(2013) Risks of Offshore Oil Drilling: Causes and Consequences of British Petroleum Oil Rig Explosion. Aquatic Science and Technology 2013, Vol. 1(1) 101 -118.

[6] Osuji, L.C. (2001) Post impact assessment of Oil Pollution in Agbada West Plain of Niger Delta, Nigeria: Field Reconnaissance and Total Experience Hydrocarbon Content. Journal of Applied Sciences and Environmental Management, 5(35) 1569-1578.

[7] Olumide A. (2017) Risk Analysis Of Oil Spillage In Niger Delta Marine Environment. Project submitted to The Department of maritime Management Technology for the Award of B.Tech. in Maritime Management Technology.

[8] IOGP (2016).An Annual Publication of the International Association of Oil and Gas Producers (IOGP).

[9] USCDC (2010) Publication of the United States Center for Disease Control, 2010 edition.

[10] Olav Kallenberg (2002) Foundations of Modern Probability, 2nd edition. Springer Series in Statistics. New York, pp 650. ISBN 0-387-95313-2

[11] Olav Kallenberg (2005) Probabilistic Symmetries and Invariance Principles. Springer - Verlag, New York (2005). pp 510. ISBN 0-387-25115-4.

Appendix1:

Table 4.1: Number/frequency accidents in upstream/offshore drilling operations in Nigeria.

Table 54: accident report – upstream incident date	Incidents	Work related	Non-work related	Fatal incidents	Non-fatal incidents	Work related fatal incidents	Non-work related fatal incidents	Fatality
2010	41	18	23	17	24	3	14	18
2011	44	21	23	17	27	5	12	17
2012	48	26	22	26	22	11	15	34
2013	45	17	28	16	29	5	11	28
2014	32	8	24	13	19	0	13	14
2015	35	11	24	23	12	6	17	50
2016	33	9	24	15	18	2	13	24
2017	41	13	28	18	23	7	11	18

Source: Nigeria Oil and gas report 2017.