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An Analysis of Determinants of Accident Involving Marine Vessels in Nigeria's Waterways

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Abstract

Cases of marine vessel accident involving personal injury, deaths, property and environmental damage have grown in tandem with increased oil prospecting and other commercial seaborne transportation activities in Niger-Delta/coastal regions of Nigeria. The incidence of marine vessel casualties and associated risk factors generate serious concern as further empirical evidence suggests that between 75-96% of marine vessel casualties are caused at least in part by some form of human error. This study investigates the determinants of accident involving marine vessels in Nigeria's waterways. Perceptual data analysed in this study were obtained from structured questionnaires administered to a random sample of marine vessel operators in marine terminals and anchorage locations. Findings from parametric tests using multinomial logit regression model indicate that human and environmental factors significantly affect probability of accident involving marine vessels. Policy implications of the results are discussed.

Key words: Marine vessel accident; Human factor; Environmental factor; Abandoned wrecks; Navigation; Coastal waterway; Niger Delta

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INTRODUCTION

A vessel accident is an unintended happening. Its severity may vary from no vessel damage to the complete loss of the vessel, no cargo damage, to loss of the entire cargo, and no crew injuries to deaths (Talley, Jin, & Kite-Powell, 2005). Thus, vessels safety regulations and their enforcement focus on prevention and reduction of severity of marine vessel accident. Accident involving marine vessels is common in inland and coastal navigation where requisite safety regulation may not be strictly observed. This is of serious consequence since such occurrences impact on safety of shipping in inland/coastal and inland waterways especially in developing countries.

In recent times, cases of marine vessel casualties involving personal injury, deaths and property/environmental damage have grown in tandem with increased vessel traffic associated with oil prospecting activities and other commercial seaborne transportation in Niger-Delta/coastal regions of Nigeria. For example, statistics (cumulative figures) based on the study carried out by Dogarawa (2012) indicate that between year 2000 to 2009, a total number of five hundred and fifty-two (552) persons died either as a result of marine vessel and boat capsizing or collision in inland waters of Nigeria. This figure indicates an average fatality rate of about 55 deaths per year excluding vessel and cargo losses, in Nigeria's coastal and inland waterways in the last ten years. Based on anecdotal evidence from some of the investigated cases; over-loading, excessive speeding, poor attention to weather condition, abandoned wrecks on navigation channels, incompetence and inadequate navigational aids are implicated. Across the globe, similar cases of marine vessels accidents at sea (and in seaports) have been documented. For example: Darbra and Casal (2004) conducted a study on 471 cases of marine accidents that occurred from 1941-2002 in Hong Kong. They observe that 57% of the accidents occurred while vessel was underway at sea and 43% of accident in ports. Various causal factors have been documented; for example, the Maritime Safety Authority of New Zealand asserts that between the periods of 1995-1996; 49% of marine vessel incidents were attributed to human factors, 35% due to technical factors while 16% were caused by environmental factors. Similarly Rothblum (2002), reports that between 75 and 96% of marine vessel casualties are caused atleast in part by some form of human error. Further empirical evidence also indicates that human error accounts for 84-88% of tanker accidents, 79% of towing vessel groundings, 89-96% of collisions, 75% of all collisions, 75% of fires and explosions (Rothblum, 2002). Similarly, Talley et al. (2005) observe that UK Thomas P&I Club survey of 1,500 insurance claims for shipping accidents around the world between 1987 and 1990, had found that 90% of the accidents were caused by human error. Two-thirds of the accidents involving personal injury claims were due to human error, e.g. carelessness or recklessness under commercial pressures, a misplaced sense of overconfidence, or a lack of either knowledge or experience. Human factor in this context is defined by Rothblum (2002) as one of the following: incorrect decision, an improperly performed action, or an improper lack of action (inaction). These statistics are disturbing given the level of measures so far adopted by local and international organizations to improve the standard of shipping and navigation.

Maritime safety is governed by the combination of international rules and regulations, national regulations of the flag states and port states, port regulations, rules of the Classification Societies and Insurance Companies. In addition, quite a number of conventions have been ratified by contracting governments some of which include: International Conventions on Safety of Life at Sea (SOLAS), Standards for Training and Watch Keeping (STCW); International Convention for the Prevention of Pollution from Ships (MARPOL). Others are International Convention on Loadlines (LL) and Convention on International Regulations for Preventing Collision at Sea (COLREG) etc. This regulatory system, which is supported by the Safety Management Systems of the shipping companies serve as a framework for continuous assessment of safety regimes in the world maritime industry. Prior to 1998, the focus of ratified IMO safety conventions was the vessel, e.g. its construction and equipment, rather than human actions aboard the vessel. The subsequent introduction of IMO's International Management Code for the Safe Operation of Ships and for Pollution Prevention changed the focus from the vessel to human actions on board vessel. By this code, shipping lines are now required to document their management procedures for detecting and eliminating unsafe human behavior. This shift towards regulating human actions aboard a vessel was motivated by the fact that: (i) most vessel accidents are caused by human error; (ii) vessel accident claims are often attributed to human error; and (iii) it is less expensive to change human behavior than it is to redesign vessels for safety (Talley, et al., 2005).

The key to preventing marine vessel accident caused by human related factors however is to identify the types of risk factors, and then apply relevant intervention to check those factors in the future. Many operators undertake such efforts internally, and the IMO and industry trade groups have made significant advances in developing prevention programs that address human factors. However, there is room for improvement, both in terms of preventive initiatives and the metrics used to gauge their effectiveness. The outcome of this research will improve both our understanding of the contribution of human and other causal factors of accident involving marine vessel and hence support implementation of prevention measures that effectively target these factors. The objectives of this study are to:

i. Assess the incidence of marine vessel accidents in Nigeria's waterways.

ii. Determine the risk factors that lead to marine vessel accidents in Nigeria's waterways.

Consequently, we postulate and test the following hypothesis at $\alpha = 0.05$:

i. Human factors related to safety training, overloading of vessel and speeding are not significant causes of marine vessel accident.

ii. Environmental factors related to wind, visibility, sea condition and weather condition do not significantly cause marine vessels accident.

iii. Marine vessel equipment/machinery failure is not significant causal factor of accident.

1. LITERATURE REVIEW

Kite-Powell and Talley (2012) investigate the determinants of the vessel damage severity of cargo vessels involved in accidents using the US Coast Guard data covering the period 2001-2008. Four types of cargo vessel (freight barge, freight ship, tank barge and tanker) were considered in the study. The basic research questions were to find if the accident vessel damage severity of cargo would likely be greater for a certain type of vessel, vessel accident, vessel characteristic, visibility condition, vessel propulsion, hull construction and season. The findings suggest that freight ships are less vulnerable to vessel accident damage than freight barges, tank barges and tankers. Freight barges are found to be more likely to incur more vessel damages and total loss. Older vessels are more prone to accidents at nights while large vessels with steel hulls are expected to incur less vessel damage if the accident occurred in summer. Abandoned vessels are prone to total loss in the event of accident.

Özgecan et al. (2008) employ simulations to model safety risk factors affecting transit maritime traffic vessels underway the strait of Istanbul. These factors include vessel arrival rates, scheduling pilotage, overtaking policies, and local traffic conditions. Safety risk analysis was performed by incorporating a probabilistic accident risk model into the simulation model. A mathematical risk model was developed based on probabilistic arguments regarding instigators, situations, accidents, consequences and historical data as well as subject-matter expert opinions. Scenario analysis was carried out to study the behavior of the accident risks, with respect to changes in the surrounding geographical, meteorological and traffic conditions. This framework enabled the investigation of the impact of various factors on the risk profile of the Strait. Local traffic density (environmental factor) and pilotage were identified as the two main factors affecting the risks at the Strait of Istanbul. In addition, the model indicates that pilots are of utmost importance for safe transit and lack of pilotage (human related factor) significantly increases the risks in the Strait. The conclusion of this study recommends the availability and deployment of more pilots to support the transit vessels in their navigation through the Strait.

Psaraftis et al (1998) conduct a comprehensive analysis of the human element as a factor in marine accidents. The object was to investigate relationship between the various probable causes of an accident and the final outcome of the accident. The study finds that factors related to human errors: communication, organization procedures and routines, individual onboard situations, judgment and reactions constitute the single most common cause of marine accidents. Talley (2002) analysed the determinants of the fatal and non-fatal crew injuries of individual commercial US and foreign flag bulk container and tanker vessel accidents (investigated by the US Coast Guard for the time period 1981-1991). Empirical results suggest that the number of fatal crew injuries is greater for: (i) tankers than for container or bulk vessels, (ii) fire/explosion accidents than for other types of accidents; and (iii) multiple-than for single-vessel accidents. Non-fatal crew injuries are also greater for fire/explosion and multiple-vessel accidents. In a related study of towboat vessel accidents, Talley (2002) also found that the number of both fatal and non-fatal accidents is greater for (i) Docked or moored vessels than for underway vessels; and (ii) fire/explosion accidents than for other types of accidents.

Leck (2008) proposes a framework for incorporating weather condition criterion in performing risk analysis that pertains to ships underway at sea. Thus, all forces of the sea should be decomposed into hazardous situations and other possible ship capsizing scenarios. Using event and fault tree analytical tools, the probabilities associated with these scenarios should then be analysed.

Wang et al. (2002) assess ship performance in accidents and propose a framework for design of robust marine structures that can endure in accidents. Building on data obtained from three criteria; definition of accident scenarios, procedures for evaluating consequences, and criteria for approval or acceptance of a design; the framework suggests inputs that can be employed in the design of marine structures robust enough to sustain ships integrity and minimize damage to the environment in marine accidents. Jina and Eric (2005) however were more concerned with management of fishing safety and modeled accident involving fishing vessels using logit regression and daily data collected from 1981 to 2000. The study found that higher wind speeds are associated with greater accident probability and that accidents are more likely to occur closer to shore than offshore. In a related theme, Wang et al (2005), investigate causes of accidents involving fishing vessels in the UK using secondary data. Data analysis indicates that machinery damage contributes over 50% of all accidents. Other factors include flooding and foundering, grounding, collision and contact. In port locations, Yip (2008) investigates port traffic risk employing historic accidents records involving oceanic ships which visited Hong Kong port. Using negative binomial regression model, it was found that collision accidents are the frequent incidents in heavy port traffic situations. Passenger-type vessels were found to have higher potential for injuries during accidents. Among the variables tested which explain occurrence of accidents; vessel's port of registry, type of vessel, type of waterway were found significant.

Lin et al. (1998) present an analysis on the factors contributing to groundings when ships transit in and out of ports. Using grounding location database generated and verified with United States Coast Guard's grounding accident data, two factors were analyzed—tide and time of day. The results suggest that tide forecast error (predicted tide water level minus observed tide water level) had no significant effect as a risk factor, and that night navigation was far more risky than day navigation. Most of the studies reviewed so far were based on historical data collected while others were simulations meant to analyse risk scenarios. The review so far may not be exhaustive but rather provides a bird's eye view of relevant factors and scenarios that explain marine vessel causalities at sea. These can be grouped under human, machine and environmental factors. The present study contributes to the existing knowledge by building on the findings from previous works to assess their validity with perceptual data on marine vessel accident in Nigeria's waterways. In spite of limitations associated with rating response data (which may be prone to subjective influences), the data set of the present study is enriched since they were based on direct account of analytical units (the marine vessel operators) and not historical records.

2. RESEARCH METHODOLOGY

The study investigated cases of accidents involving marine vessels in Nigeria's coastal and inland waterways. There are many rivers and rivulets along Nigeria's coast. Prominent among them are the Ogun River in the West which flows into the Lagos Lagoon thus creating the calm waters that have sustained the ports in Lagos; the Benin River from which the maiden shipment of export produce was done in the Middle Ages and on which the natural port of Koko now stands; the Escravous and Forcados whose terminals host the Crude Oil Tankers; the Bonny River which provides Port Harcourt with an outlet to the sea and the Cross River system with Imo and Qua-Iboe Rivers. The area of the study is therefore Nigeria's waterways which cover Lagos Island, Bonny River, navigable creeks and oil terminal locations in Niger Delta, the Escravous, Forcados and Calabar coastal areas. Data on marine incidence within these areas were obtained from questionnaires administered to marine vessel operators. The resort to cross section primary data collection became necessary owing to absence of reliable official records on accidents involving marine vessels.

The sample population of this study consisted of Captains and Chief mates of marine vessels that operate within Nigeria's coastal and inland waters. The marine vessels surveyed include mainly service boats, freight barges, fishing vessels, tank ships and tug boats. Vessels flying both Nigerian and foreign flags were included. To draw the sample frame, the list of all registered ship operating companies (foreign and domestic flags) with their addresses was obtained from the records of Nigeria Maritime and Safety Agency (NIMASA) and Nigeria Shipping Company Association (NSA). However, initial effort to reach most of them at their base offices proved abortive as some had changed addresses and others did not co-operate. Thus, it became imperative for the researcher to visit the "field men" (ship captains and chief mates) in the terminals and anchorages. For the purposes of this study, a marine vessel operator is defined as the Master of the vessel or his Chief Mate. Chief Mate is considered in the absence of the Captain since he takes over control of the affairs of the vessel when the captain is on leave or indisposed. Eleven clusters were randomly selected for sampling in the study. These are; Lagos anchorage, Bonny anchorage, Calabar anchorage and Nigeria's eight port terminals. These clusters represent the anchorage of most of the marine vessels that operate on Nigeria's coastal and inland waterways. The number of annual vessels' calls to these terminals and anchorages was collected from their signal offices. This was used to determine the sample size in each cluster. Structured questionnaires based on five point Likert scale were administered to the sample of marine vessel operators. The questions were worded so as to elicit information on nature and probable cause of marine incidences they had encountered while at sea. The questionnaires also provided for their responses regarding other human, environmental and vessel characteristics which they consider as related to such incidences. In all, a total of three hundred and ten questionnaires completely filled were finally considered for data analysis. The data were analyzed using both the descriptive and inferential statistical techniques. The statistical model applied for the inferential statistics is the multinomial logit model.

2.1 Derivation of Empirical Model: The Multinomial Logit Model Formulation

Multinomial logit model is used to model relationships between a Polytomous response variable and a set of regressor variables. Polytomous response model can be classified into two distinct types, depending on whether the response variable has an ordered or unordered structure. In an ordered model, the response Y of an individual unit is restricted to one of n ordered values. In an unordered model, the Polytomous response variable does not have an ordered structure and the values are hence nominal. Nominal values are used to represent observed values of the categories of the Polytomous dependent Y which is latent. In this study, we assume the observed outcome response variable is both latent and nominal.

Thus, we model the outcome response variable Y_i as the probability that the ith marine vessel operator is involved in a fatal, non-fatal or damage accident. Since Y_i is a latent variable, we observe y_i^* which takes nominal and discrete values. For example, y_i^* takes the value of 1 if vessel accident category is Fatal, value of 2 if non-fatal accident is occurs and assumes the value of 3 if damage accident results instead. Hence we propose the multinomial model as follows:.

Let $\pi_{ij}=pr\{y_i=j\}$ (1) denote the outcome probability of jth accident category, where $i=1,...,N$ and $j=1,...,3$.

For example, π_{i1} is the probability that the ith vessel operator had a fatal accident. Thus, we now model the outcome probability that π_{i1} depend on a vector X of covariates or the risk factors associated with marine vessel incident. i.e. we model based on the hypothesis that the probability of marine vessel operator involved in fatal, Non-fatal or Damage accident depends on the postulated Human, Machine and Environmental factors (as covariates). Mathematically this can be shown as in Greene (2003):

$$\pi_{ij} = p_r\{y_i^* = j \mid x_i\} = \frac{e^{\beta' jxi}}{1 + \sum_{K=1}^{J} e^{\beta' kxi}} \quad for\ j = 1,...,J\ ,\ x = 1,...,N \tag{2}$$

For multinomial data, we nominate one of the response categories as a base outcome. We then calculate log-odds for all other categories relative to the base outcome as:

$$\ln\left[\frac{\pi_{if}}{\pi_{id}}\right]$$

where π_{if} = the probability of the ith operator sustaining fatal accident and

π_{id}= the probability of the ith operator sustaining damage accident (the base outcome).

The dependent variable, log-odds is a linear function of the predictors. In the multinomial logit model, the log-odds of each response follow a linear model. We have J response categories and therefore we would have J-1 different multinomial equation systems, because the coefficients of the last equation can be calculated from the coefficients of the first J-1 equations. Based on the foregoing, we specify our empirical models for this research as follows:

$$\ln\left[\frac{\pi_{if}}{\pi_{id}}\right] = X_i'(\beta_f - \beta_d) \tag{3}$$

$$\ln\left[\frac{\pi_{in}}{\pi_{id}}\right] = X_i'(\beta_n - \beta_d) \tag{4}$$

where π_{if} is the probability that the ith operator is involved in a fatal accident *(f)*; π_{in} is the probability that the ith operator gets involved in a non-fatal accident *(n)*; damage accident *(d)* being the reference category. X_{if} andX'_{id} are vectors of explanatory variables representing Human, Environmental and Machine factors associated with fatal and damage accident respectively. β_k is a vector of parameters of the multinomial equations (3) and (4) to be estimated; where subscript $k=d,f,n$ denotes accident type.

2.2 Maximum Likelihood Estimation of The Model

Estimation of the parameters of this model is by maximum likelihood. The likelihood function for a sample of N independent observations is the product of N densities, so $L = \prod_{i=1}^{N}\prod_{j=1}^{J} p_{ij}^{yij}$ The maximum likelihood estimator (MLE) $\hat{\theta}$ maximizes the log-likelihood function:

$$\ln L(\theta) = \sum_{i=1}^{N}\sum_{j=1}^{J} y_{ij}\ln F_j(x_i,\theta)$$

where $F_j(x_i,\theta)$ is the functional form specified as above and as usual $\hat{\theta}\sim N(\theta,[-E\{\partial^2\ln(\theta)/\partial\theta\partial\theta'\}]^{-1})$, see Cameron and Trivedi, 2009.

The multinomial logit model was implemented in Stata (version 12 for windows).

3. DATA PRESENTATION AND ANALYSIS

Table 1 below presents a summary of attributes of the marine vessel operators sampled. In terms of sailing experience, the table shows that 45% of those sampled have had sailing experience that ranges between 18 and 24 months of sea time. While 26% have experience spanning over 24 months.

Table 1
Descriptive Statistics of Sample Data

Attribute	Freq.	Percent	Cum.
Experience of the vessel operator (sea time)			
Under 6 months	33	10.65	10.65
6 to 12 months	58	18.71	29.35
18 to 24 months	139	44.84	74.19
Over 24 months	80	25.81	100
Safety training received by vessel operator			
Non	34	10.97	10.97
Inhouse training	60	19.35	30.32
NIMASA training	70	22.58	52.9
Educ institutn	101	32.58	85.48
Cross-border training	45	14.52	100
Type of accident involved			
Fatal	57	18.39	18.39
Non-fatal	145	46.77	65.16
Damage	108	34.84	100
Total	310	100	

Thus, the majority of those sampled (> 90%) have had considerable sailing experience and hence could have given valid responses to the questionnaire items. Based on the distribution of accident by type as shown in table 1, Fatal and Non-Fatal Accident accounted for over 65% (cumulatively) of accident cases. While Damage accident accounted for approximately 35% of accidents involving marine vessels that occurred during the study period.

Table 2
Summary of Regressor Variables

Variables	Mean	Std. Dev.
Human factors		
Alcohol use	3.565	1.267
Overloadn	1.887	0.957
Improper lokout	2.235	1.064
Machine factors		
Equipment failure	2.6	1.095
Machine failure	1.965	1.074
Environ. factors		
Sharp turns	2.235	1.188
Abandoned wrecks	2.977	1.38

Note: Total No. of Obs: 310

Table 2 shows the mean values of rating response of the sample vessel operators regarding the risk factors (variables) which they consider as causes of accident involving marine vessel operations.

Figure 1 above shows that for the fatal accident category, Human factors accounted for more than 50% of marine vessel accident risk factors. This is followed by environmental factors which accounted for over 30% of the cases, while Machinery failure accounted for less than

20%. Thus by inspection, these factors likely constitute the main risk factors for the cases of marine vessel incidents under study.

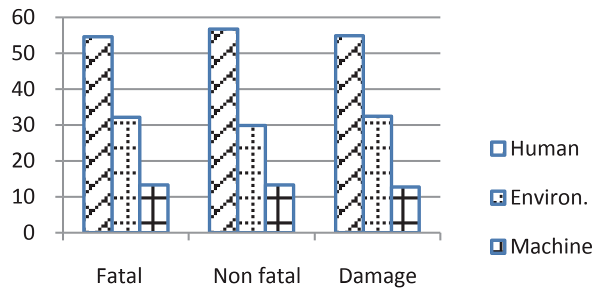

Figure 1
Distribution of Accident Types and Associated Risk Factors

3.1 Analysis of Accident Causative Factors

In Table 3, the output of the multinomial logit model regression is presented. Only significant variables were retained in the model using stepwise procedure. The result indicates that the following human related risk factors significantly affect the probability of occurrence of accident involving marine vessels: level of sailing experience of the vessel operator, level of watch keeping duties and speed level of the vessel. These variables have significant *p*-values and are significant factors that explain accident involving marine vessels. Other significant factors which are related to the sea environment include: weather condition at sea, abandoned wreck at navigation channels.

Table 3
Multinomial Logit Model Regression Output

Variables	Coef.	*Std.* Err.	*t*-stat	*p* >|t|
Fatal[a]				
Vsl speed	3.229***	0.474	6.81	0.000
Experience	-1.129***	0.329	-3.43	0.001
Weathr cond	-0.628**	0.255	-2.46	0.014
Aband wrecks	0.805	0.741	1.09	0.277
Impr lokout	-0.655**	0.312	-2.1	0.036
Constant	-4.743	1.836	-2.58	0.010
Non-fatal[a]				
Vsl speed	0.348	0.221	1.58	0.115
Experience	-0.596***	0.186	-3.21	0.001
Weathr cond	-0.426***	0.103	-4.12	0.000
Aband wrecks	-0.839***	0.297	-2.82	0.005
Impr lokout	-0.373***	0.138	-2.7	0.007
Constant	3.81	0.921	4.14	0.000
Damage[a]	*(base outcome)*			
Number of Obs.310				
LR chi2 (10) = 261.030				
Prob > chi2 = 0.000				
Pseudo R2 = 0.407				
Log likelihood = -190.070				

[a]Dependent variable; ***,**,* Significant at $p<1\%$, $p<5\%$ and $p<10\%$ respectively.

CONCLUSION

Safety of navigation and life at sea are important to coastal, flag states and the entire international shipping community in sustaining the growth of global seaborne trade. National governments and indeed the Federal government of Nigeria have committed considerable resources and efforts on programmes aimed at reducing the incidence of accident involving marine vessels at sea. For instance, the Maritime Administration of Nigeria recently expended considerable resources in clearing the waterways of abandoned wrecks to make for safe navigation. Again, The Maritime Guard Command (akin to the US Coast Guard) has been inaugurated to enforce shipping regulations. These efforts can greatly be enhanced by targeted intervention policies based on empirical analysis which identify specific accident risk factors. The categories of accident investigated in this study are fatal, non-fatal and damage accident. Results indicate that over 65% of accidents at sea involving marine vessels were of fatal and non-fatal category. Three categories of causality factors were of consideration in the study. These are human, environmental and machinery factors. The Human related factors accounted for over 50% of variations in the categories of accident investigated. This is followed by environmental factor which accounted for 30% while machinery factors accounted for 20% of accident risk factors. The human factors include the following: experience acquired by the vessel operator, safety training received, stowage condition of the vessel (overloading), and level of watching keeping maintained (improper lookout). These findings have implication on regulation and enforcement by relevant authorities. The level of regulation maintained by the flag states can reduce the contribution of these factors to accidents involving vessels at sea. Environmental factors investigated are: sea condition (current) and weather condition during navigation. Machinery factors include: equipment or machine failure. Environmental factors influences can be controlled to some extent by maintaining relevant database on tidal and weather forecasts. These results call to question the level of regulation or coastguard inspection by the responsible authority in Nigeria. Based on the findings of Dogarawa (2012), most marine crafts operating in Nigeria's coastal and inland waterways are not registered (perhaps in attempts to evade taxation). This situation renders inspections on vessels' construction and operating conditions difficult. Consequently, marine vessel accident would likely not be reported to the responsible authority to avoid arrests. Presently, it is not clear which government parastatal is responsible for coastguard duties. Although there is statutorily in place The Maritime Guard Command which is jointly operated by The Nigerian Navy and Personnel of Nigeria Maritime and Safety Agency (NIMASA) for coast guard responsibilities; but there appears to be a conflict of interests among other stakeholders: Nigeria Ports Authority (NPA), Nigeria Maritime Administration and Safety Agency. There is considerable overlap of responsibilities of these organizations as provided in the Acts establishing them and this could be a source of the conflict. Thus, it has become imperative in view of safety of navigation, for the Federal government to resolve these issues and establish the responsible organization for coast guard duties. This study attempts to model marine vessel accident risk factors empirically using evidence from a developing country's context. The cross sectional and largely perceptual nature of the data employed for this research may affect the generalizability of the findings. Perhaps, an enriched panel data describing marine vessel incidents and experiences of the operators over time may likely produce more robust results in future studies. Owing to the obvious limitations in data availability, no attempt was made to disaggregate the study based on classes, types of marine vessels and associated risk factors. Future efforts should therefore consider a more disaggregated study.

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