Social Science and Humanities Journal
Everant Journal
ISSN: 2456-2653
https://sshjournal.com/
Impact Factor: 2024: 6.576
2023: 5.731
Volume 09 Issue 09 September 2025
DOI: https://doi.org/10.18535/sshj.v9i09.2032

A study on Statistical Analysis of Container Ships Accidents and Preventive Measures

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Received 14-08-2025
Revised 13-09-2025
Accepted 16-09-2025
Published 19-09-2025

Abstract:

As more cargo being carried by container vessels due the influence of international trade, containerships have recorded a constant growth from1980s onwards both in number and size which came with the increasing number of accidents hence the importance of conducting study on response measures. This paper presents the results of comprehensive analysis of recorded containerships accidents that occurred between 2011 and 2019 from official way by using statistical methods such as frequency distribution, cross tabulation and Chi-square ($\chi2$). This paper established several findings as following: most containership accidents are due to human errors; there is a significant statistical relationship between type of containership accident and causative reason, sea area (zone), ship's status and ship's age; there is no statistical relationship between type of accident and size of a containership.

Keywords: Container ship; Accidents, Chi-square analysis, Human error.

1. Introduction:

Container vessels, have gained increasing visibility and relevance in international trade over the years. Over 90% of the world's non-bulk cargo that are carried by ships makes use of containers. Consequently, container vessels have recently become an increasingly important part of the global logistics value chain of a market which has recorded a constant growth from 1980s onwards.

The statistics portrays the number of container ships in the world merchant fleet to be 5,502 containerships that were serving sea routes worldwide in 2019. China, Japan, and South Korea were the world's major shipbuilding nations in 2018 while the carrying capacity of the global merchant fleet reached roughly 1.9 billion deadweight tons in 2018. Based on the chartered twenty-foot equivalent units (TEUs), Mediterranean Shipping Company is the leading container ship operator worldwide.

The objective of this paper attempts to analyze the container ships accidents occurred in the scheme period of 2011 to 2019 by using statistical methods and Chi Square ($\chi2$) Analysis. The purpose of the study being identification of further required measurements to ensure safety navigation. The critical analysis of these accidents will enable to ensure safety navigation and marine environmental protection.

2. Literature review:

In the study "Analysis of ship accidents in the strait of Istanbul" by (Ece, N.J.,et al., 2012) the author used Chi Square ($\chi2$) Analysis to analyze ship accidents in the strait of Istanbul . On this study which involved the accidents which occurred from years 1982 to 2021 it was observed that most accidents in Istanbul strait occurred between the years 1982 to 1993 before maritime Traffic regulations were implemented. Also the study concluded that the number of accidents dropped after the implementation of the vessel traffic Services (VTS) in the year 2004.

In the study "statistical analysis of ship accidents and review of safety level" the author used statistical frequency distribution to study and analyze the trend of accident yearly from 2000 to 2012. Moreover, this study presented the analysis of possible relationships between accidents rates and ship's age where by the author proved more complex relationship between the two indicators since it was not straight forward that older ships suffered more accidents than younger ships.

3 Container ship fleet and Risk factors:

According to the IMO, container vessels/ships are the cargo ships that carry their entire load using a technique called containerization in truck-size intermodal rectangular boxes called containers.

APM- MAERSK shipping company is the leading company with almost 713 container vessels as of March 2021 which accounts to 4.1 million TEU capacity. Currently HMM Algeciras is the world's largest containership with 24000 TEU capacity which is in one twelve 24000 TEU class vessels eco-friendly container vessels. HMM Algeciras is the Panama flagged vessel which measures 399.9 meters in length and 33.2 meters in depth designed and constructed by Daewoo Shipbuilding and Marine Engineering.

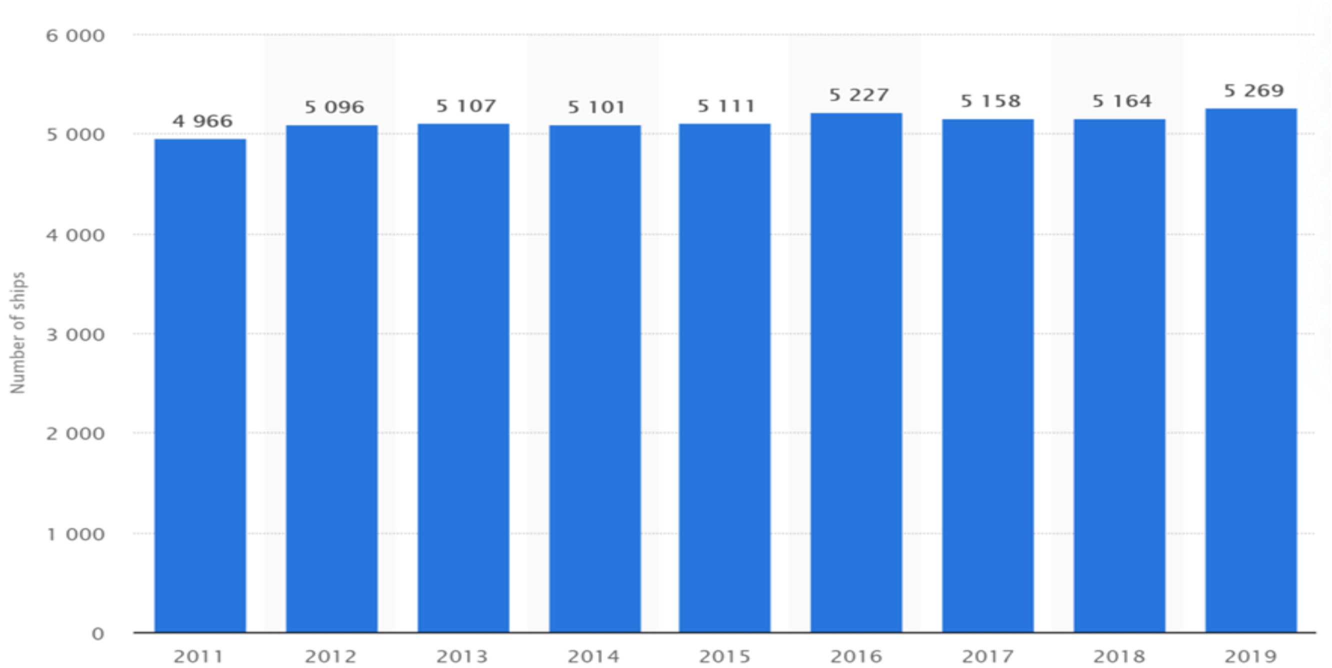

Fig 1: Containership fleet status from 2011 to 2019

Risk features of a containership cargo are categorized into four aspects as follows.

i. Risk Features of containership cargo

   Dangerous cargo (harmful, explosive)

   Perishable if not proper stored, Container losing if not properly secured (due to wind and waves.

ii. Containership loading and unloading risks

   Slips, trips and falls

   Container struck by quay crane

   Container struck by quay crane

   Worker struck by falling hatch cover or container

iii. Risk Factors of deck structure.

   Blocking the line of sight; Containers stowed on exposed decks must be stowed so that they do not obstruct the Navigation Bridge's view.

iv. Risks factors of cargo hold structure.

Confined space, Slip and falls

4 Methodology:

4.1 data collection

2171 containership accidents historical data from 2011 to 2019 were collected from European Marine Casualty Information Platform (EMCIP) in official way, these data included time of

accident occurrence (year), Age of the ship, location and reason of accident for all container ships as well as size in gross tonnage (GT) of the ship involved in the accident.

4.2 data analysis

The statistical indicators that will be analyzed are container ship accident by years, accident by type, accident by reason, accident by zone, accident by ships age, accident by ship's size and accident by ship's status when it occurred.

Descriptive statistics like frequency distribution and non-parametric statistics like the Chi Square Test has been used to describe the data in this study. To display a summarized grouping of the non-parametric data, a Frequency Distribution was used. The Chi-Square test was used to evaluate the non-parametric variables relationships by using Statistical Package Programme (SPSS) and the level of significance was set at 5%.

4.2.1 Frequency Distribution

Table.1 Frequency Distribution Table of Container Ship Accidents by Years

S N	YEARS OF OCCURANCE	NUMBER OF C/S ACCIDENTS	PERCENTAGE (%)	CUMULATIVE PERCENTAGE (%)
1	2011	112	5.2 %	5.2 %
2	2012	218	10.0%	15.2%
3	2013	215	9.9 %	25.1%
4	2014	248	11.4%	36.5%
5	2015	297	13.7%	50.2%
6	2016	276	12.7%	62.9%
7	2017	305	14.0%	77.0%
8	2018	287	13.2%	90.2%
9	2019	213	9.8 %	100%
10	TOTAL	2171		

Table 1 shows that for containership accidents from 2011 to 2019 it was observed that years 2015 and 2017 were the years with the highest frequencies of accidents i.e. 297 (13.7%) accidents and 305 (14%) accidents respectively while 2011 and 2019 being the lowest recording below the average of 241 i.e. 112 (5.2%) and 213 (9.8%) respectively. Based on the data over eight years period from 2011 to 2019, a total of 21.8% of the container ship accidents were collisions, 22.8% loss of control, 20.3% were contacts, 13.3% damage to ship equipment, 8.1% grounding/stranding, 6.7% fire/ explosion, 1.3% were listing/capsizing and 0.3% were flooding/foundering. The loss of control with 22.8% was the most recorded accident type occurred as shown in Figure 2 below.

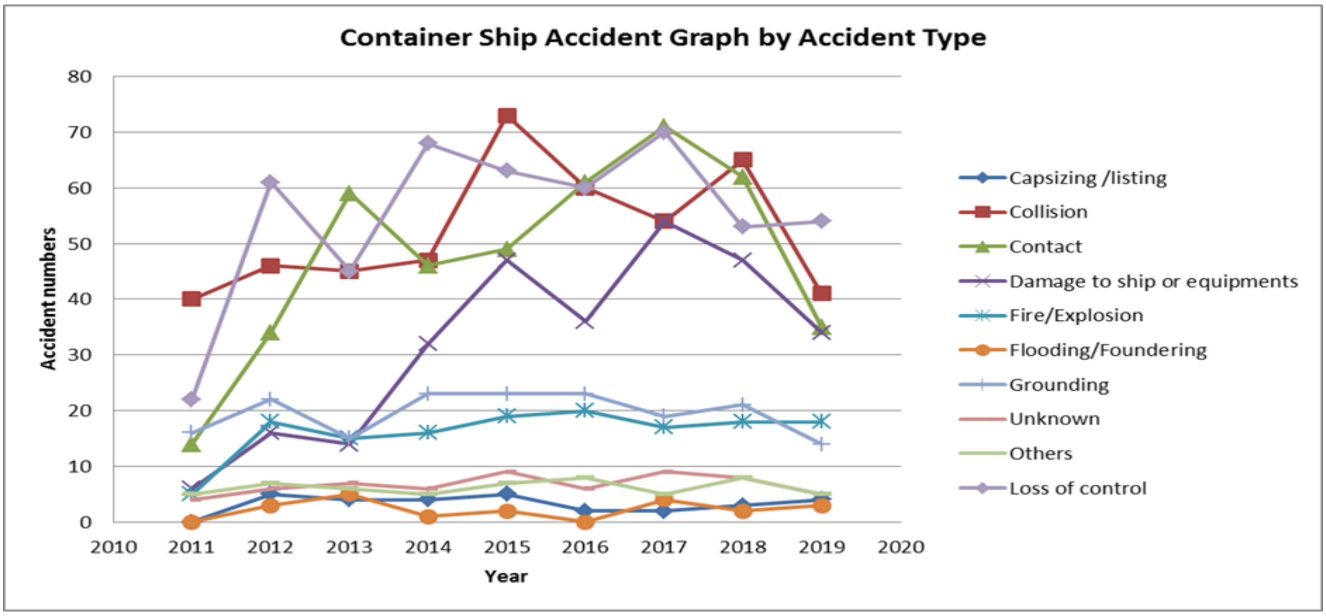

Fig.2 Frequency distribution graph of container ship accident type

Fig 3 shows that human error is the major cause of accidents with the frequency of 1563 (72%), respectively bad weather conditions and current with the frequency of 156 (7.2%), contact fishing nets recorded less accidents with the frequency of 7 (0.3%) and local traffic density with the frequency of 43 (2%).

Human error is generally accounted for 80 to 85 % of all vessels accidents at sea however in this study (container ship accidents) it has been 72%. Human error results from accidents and incidents in which the person in charge of the vessel misunderstands the lighthouse and misreads depth, angle, and distance values, insufficient technical experience, mental illness, exhaustion, professional fatigue and lack of proper training.

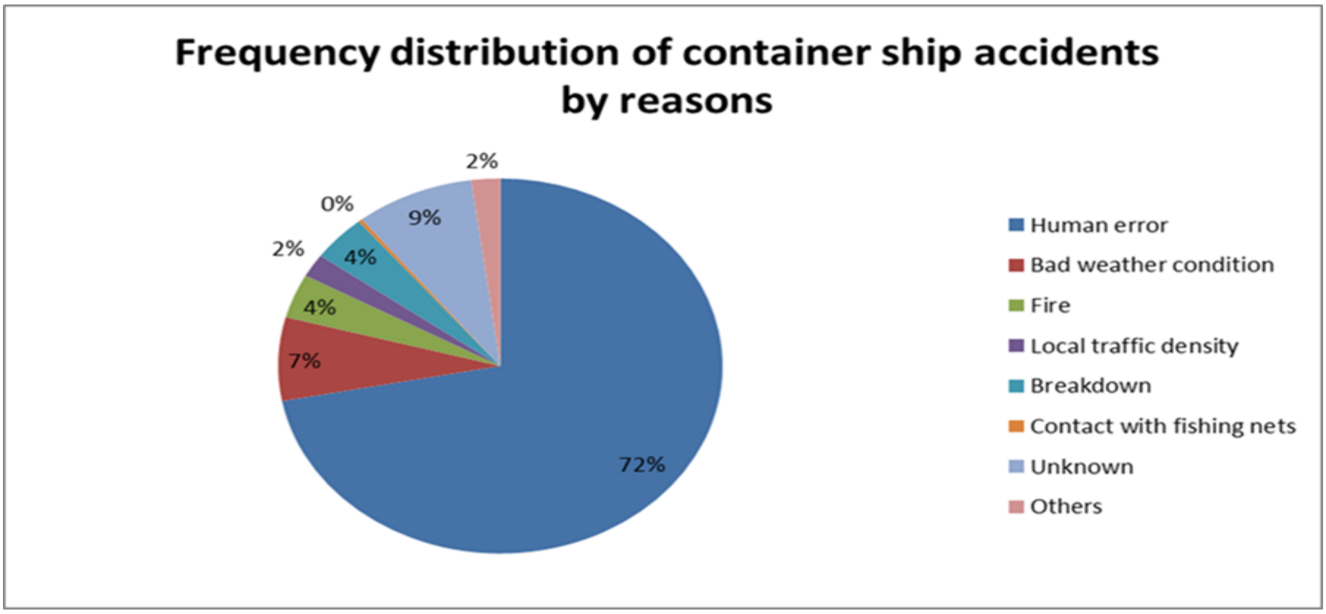

Fig.3 Frequency distribution of container ship accidents by reasons

In terms of occurrence distribution by sea area (zone), most containership accidents about 47.63% of all accidents occurred in Internal waters port areas, while 18.84% occurred in open sea (in/outside EEZ), and 18.47% accidents occurred in territorial sea, as shown in the graph below.

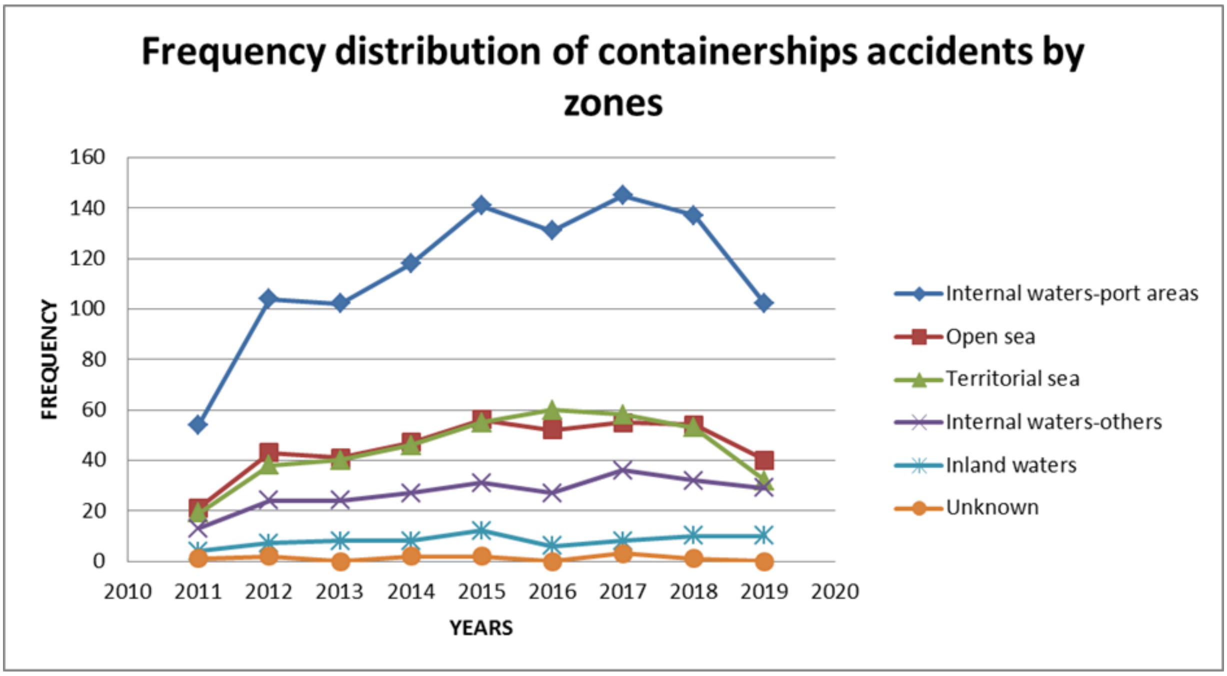

Fig.4 Graph of frequency distribution of container ship accidents by zone

According to the data collected in this study from 2011 to 2019 container ships' age was classified into five categories (groups). The first category was for ships with less than 5 years, the second category was ships with age 6-10 years, the third group had ships with age 11-15 years, the fourth category had ships age from 16-20 years, and the fifth and last category had ships with age over 20 years. It was observed that most accidents involved the containerships with age 11-15 years i.e. (26.26%) while few involved the ships that are over 20 years old (16.81%) as shown in figure 5.

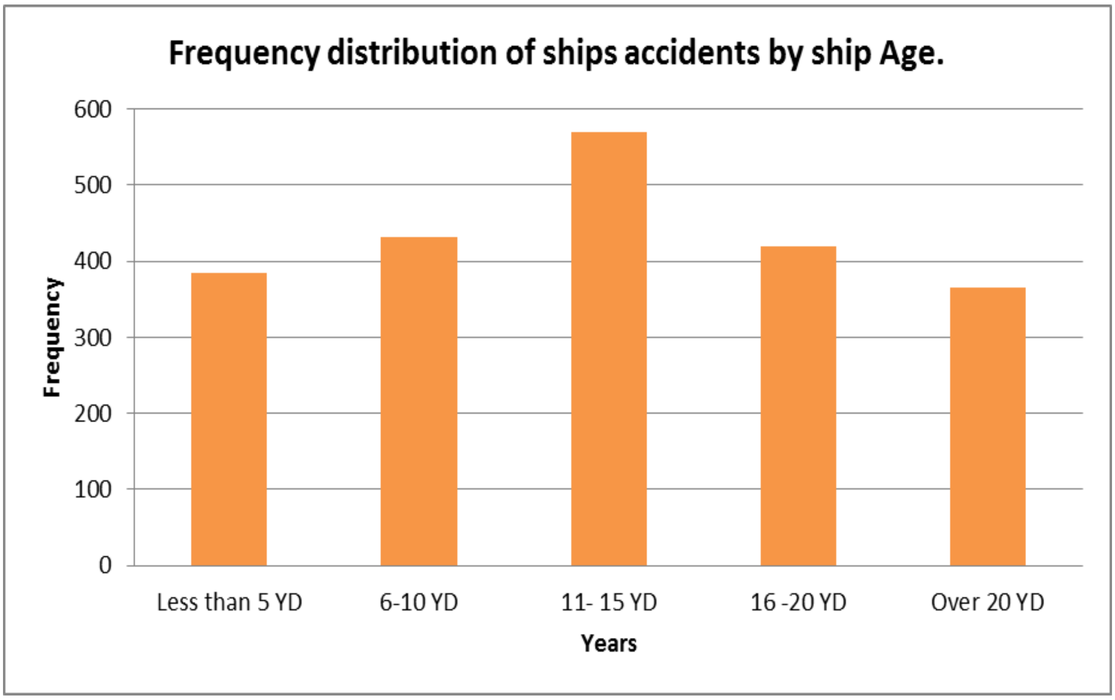

Fig.5 Graph of frequency distribution of container ship accidents by ships' age

According to the data collected in this study from 2011 to 2019 container ships the status of Container ships involved into accidents were divided into six groups namely; Ships on transit, Ships Anchored alongside, Ships on Arrival, Ships at mid water and Ships on departure.

It was observed that most ships on transit are the ones involved in most containership accidents i.e. (28.0%) and the least accidents were observed on the ships on departure i.e. (12.1%) ignoring the unknown status as shown in figure 6.

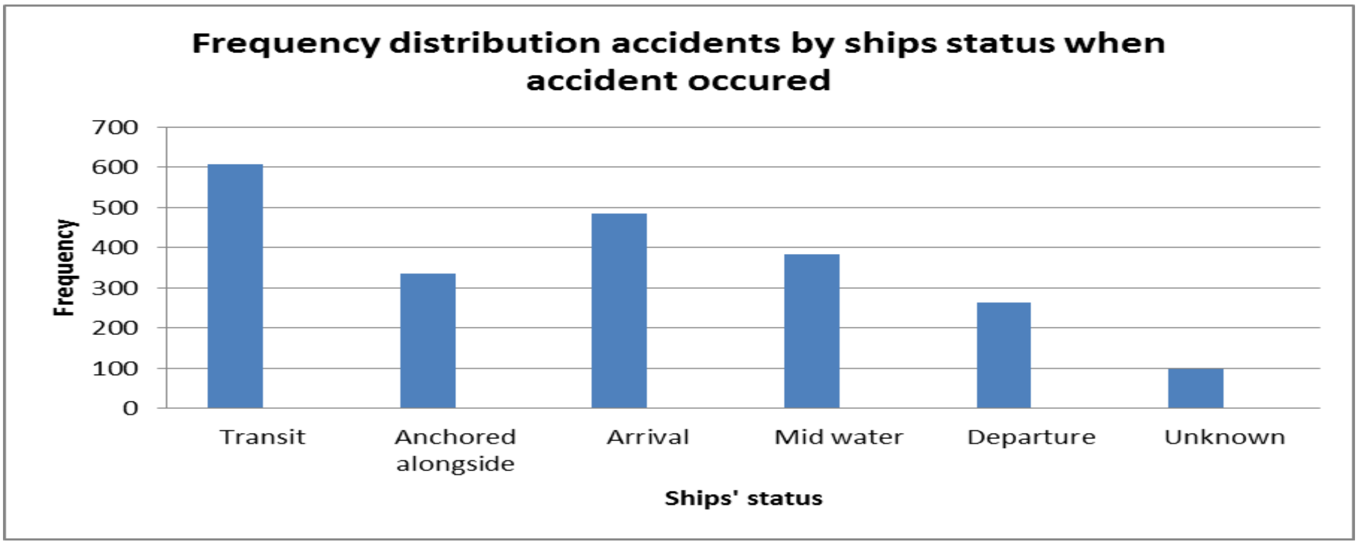

Fig.6 Graph of distribution of accidents by ship's status when accident occurred

This study divided the tonnage of ships into eight categories i.e. less than 10,000 GT, 10,000-15,000 GT, 15,000-20,000 GT, 20,000-25,000 GT, 25,000-30,000 GT, 30,000-35,000 GT, 35,000-40,000 GT, and above 40,000 GT. It was observed that Container ships with less than 25,000 GT are more prone to accidents accounting for 73.1% compared to the ships with above 40,000 GT where by only 8.38 % encountered accidents during the study period of 2011 to 2019 as shown in figure 7.

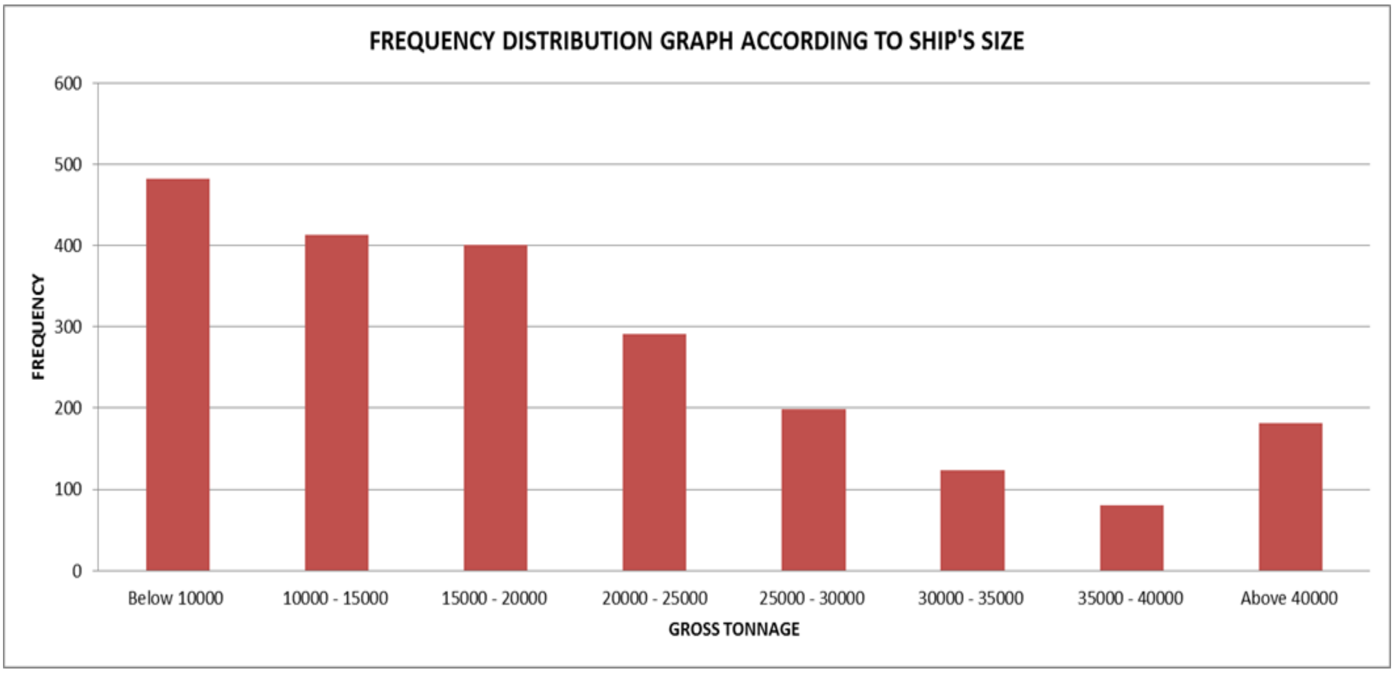

Fig.7 Graph of frequency distribution of accidents by ship's size in Gross Tonnage

4.2.2 Chi-square Analysis

Chi-square analysis/test is a statistical hypothesis test model that is used for testing relationships between categorical variables. Chi-square test is used in statistics to determine if there is significant deference between the expected values and the observed values. The null hypothesis of the Chi-Square test is that no relationship exists on the categorical variables in the population.

Reckon that n observations have been classified in k mutually exclusive classes in a random sample from population with observed numbers xi (for i = 1,2,…,k) respectively, and the null hypothesis gives the probability pi that an observation lies into the ith class. So we will have the expected numbers mi = npi for all i, where

It was tested a hypothesis H_0 that fully specifies p1,….., pk,

H_0: p1 = p1 (0), ; p2 = p2(0), …………., pk = pk(0),

The formula for the χ2 test statistic is:

$$\chi 2 = \sum_{i=1}^{k} \frac{(\textit{Observed count in cell } i - \textit{Expected count in cell } i)^2}{\textit{Expected count in cell } i \textit{ where}}$$

$$\chi 2 = \sum_{i=1}^{k} \frac{(fo - fe)^2}{fe}$$

Two hypotheses (H_0, H_1) will be established to test each indicator against Accident types.H_0 is referred as null hypothesis and H_1 is referred as an alternative hypothesis. The two hypotheses stated as follows;

H_0: There is no significant relationship between two categorical variables if P-value > 0.05.

H_1: There is a significant relationship between two categorical variables if P-value < 0.05.

The above hypothesis will be tested and their significance will be established so as to accept or reject the hypothesis.

Table2. The cross tabulation between accident type and reason of accident

Accident type * Accident reason Cross tabulation										
Accident Reason / accident Type		Unknown	Human error	Local traffic density	Bad weather	Contact with fishing nets	Fire	Breakdown	Other	Total
Unknown	Count	5	44	1	4	0	2	2	2	60
	% within Accident type	8.3%	73.3%	1.7%	6.7%	0.0%	3.3%%	3.3%	3.3%	100%
Flooding	Count	1	5	0	1	0	0	0	0	7
	% within Accident type	14.3%	71.4%	0.0%	14.3%	0.0%	0.0%	0.0%	0.0%	100%

Collision	Count	41	341	9	34	1	18	19	10	473
	% within Accident type	7.5%	75.1%	1.7%	6.1%	0.2%	3.6%	3.8%	2.0%	100%
Grounding	Count	15	125	4	13	1	7	7	4	176
	% within Accident type	8.5%	71.0%	2.3%	7.4%	0.6%	4.0%	4.0%	2.3%	100%
Fire/ Explosion	Count	13	103	3	11	1	6	6	3	146
	% within Accident type	8.9%	70.5%	2.1%	7.5%	0.7%	4.1%	4.1%	2.1%	100%
Capsizing/ listing	Count	3	20	1	2	0	1	1	1	29
	% within Accident type	10.3%	69.0%	3.4%	6.9%	0.0%	3.4%	3.4%	3.4%	100%
Contact	Count	38	317	9	31	1	17	18	9	440
	% within Accident type	8.6%	72.0%	2.0%	7.0%	0.2%	3.9%	4.1%	2.0%	100.0%
Loss of control	Count	42	358	10	35	2	19	20	10	496
	% within Accident type	8.5%	72.2%	2.0%	7.1%	0.4%	3.8%	4.0%	2.0%	100%
Breakdown/ Damage to equipment	Count	25	208	5	21	1	11	11	6	288
	% within Accident type	8.7%	72.2%	1.7%	7.3%	0.3%	3.8%	3.8%	2.1%	100%
Others	Count	4	42	1	4	0	2	2	1	56
	% within Accident type	7.1%	75.0%	1.8%	7.1%	0.0%	3.6%	3.6%	1.8%	100%
Total	Count	187	1563	43	156	7	83	86	46	2171
	% within Accident type	8.6%	72.0%	2.0%	7.2%	0.3%	3.8%	4.0%	2.1%	100%

Table 3. Chi-square test table for accident type and reason

Chi-Square Tests			
	Value	Degree of freedom	Asymptotic Significance (2-sided)
Pearson Chi-Square (χ2)	275.23a	63	0.000
Likelihood Ratio	306.368	63	0.000
N of Valid Cases	2171		

a. 10 cells (16.3%) have expected count less than 5. The minimum expected count is 1.02

From the results of Pearson Chi-Square Tests displayed in table the minimum expected count is 1.02 and 10 cells (16.3%) have expected count less than 5. Hence the Pearson Chi-Square test can be used to examine if there is a significant statistical relationship between the two variables type of the accident and accident reason.

The Pearson Chi-Square test statistic is 275.23. The null hypothesis (H_0) states that there is no relationship between type of the accident and reason of an accident. While the alternative hypothesis (H_1) states that there is a relationship between type of the accident and reason of an accident at the significance level at 5%. The test results indicated that since the P-value (0.00) is less than the significance level (α =0.05), hence the null hypothesis (H_0) is rejected and the alternative hypothesis (H_1) is accepted. Therefore, I conclude that there is a significant statistical relationship between accident type and reason of an accident.

Table 4. Chi-square table for accident type and zone

Chi-Square Tests			
	Value	Degree of freedom	Asymptotic Significance (2-sided)
Pearson Chi-Square (χ2)	392.415[a]	45	0.00
Likelihood Ratio	417.524	45	0.00
N of Valid Cases	2171		

a. 12 cells (20%) have expected count less than 5. The minimum expected count is 1.14.

According to the result of Pearson Chi-Square tests shown in table above the minimum expected count is 1.14, and 12 cells (20.0%) have expected count less than 5. Therefore the Pearson Chi-Square test can be used to determine whether there is a significant relationship between the two variables type of the accident and zone at which accident occurred.

The Pearson Chi-Square test statistic is 392.415. The null hypothesis (H_0) states that there is no relationship between type of the accident and zone at which accident occurred. While the alternative hypothesis (H_1) states that there is a relationship between type of the accident and zone at which accident occurred at the significance level at 5%. The test results indicated that since the P-value (0.00) is less than the significance level (α =0.05), hence the null hypothesis (H0) is rejected and the alternative hypothesis (H1) is accepted. Thus, I conclude that there is a significant statistical relationship between type of the accident and zone at which accident occurred.

Table 5. Chi-square table on accident type versus ship's status

Chi-Square Tests			
	Value	Degree of freedom	Asymptotic Significance (2-sided)
Pearson Chi-Square ($\chi 2$)	523.362a	45	0.00
Likelihood Ratio	552.29	45	0.00
N of Valid Cases	2171		

a 11 cells (18.3%) have expected count less than 5. The minimum expected count is .32.

According to the result of Pearson Chi-Square Tests shown in table the minimum expected count is 0.32 and 11 cells (18.3%) have expected count less than 5. Therefore the Pearson Chi-Square test can be used to determine whether there is a significant relationship between the two variables type of the accident and ships' status when an accident was occurring.

The Pearson Chi-Square test statistic is 523.362. The null hypothesis (H_0) states that there is no relationship between type of the accident and ships' status when accident occurred. While the alternative hypothesis (H1) states that there is a relationship between type of the accident and ships' status when accident occurred at the significance level at 5%. The test results indicated that since the P-value (0.00) is less than the significance level (α =0.05), hence the null hypothesis (H_0) is rejected and the alternative hypothesis (H1) is accepted. Thus, I conclude that there is a significant statistical relationship between type of the accident and ships' status when accident occurred.

Table 6. Chi square table on accident type versus ship's age

Chi-Square Tests			
	Value	Degree of freedom	Asymptotic Significance (2-sided)
Pearson Chi-Square ($\chi 2$)	250.692a	36	0.00
Likelihood Ratio	247.282	36	0.00
N of Valid Cases	2171		

a 6 cells (12.0%) have expected count less than 5. The minimum expected count is 1.18

According to the result of Pearson Chi-Square Tests shown in table the minimum expected count is 1.18 and 6 cells (12.0%) have expected count less than 5. Therefore the Pearson Chi-Square test can be used to determine whether there is a significant relationship between the two variables type of the accident and age of the ship.

The Pearson Chi-Square test statistic is 250.692. The null hypothesis (H_0) states that there is no relationship between type of the accident and age of the ship. While the alternative hypothesis (H_1) states that there is a relationship between type of the accident and age of the ship at the significance level at 5%. The test results indicated that since the P-value (0.00) is less than the significance level (α =0.05), hence the null hypothesis (H_0) is rejected and the alternative hypothesis (H_1) is accepted. Thus, I conclude that there is a statistical relationship between type of the accident and age of the ship.

Table 7. Chi square table on accident type versus ship's size

	Value	Degree of freedom	Asymptotic Significance (2-sided)
Pearson Chi-Square	62.675a	63	0.488
Likelihood Ratio	52.411	63	0.827
N of Valid Cases	2171		

a 16 cells (20%) have expected count less than 5. The minimum expected count is .26.

According to the result of Pearson Chi-Square tests shown in table the minimum expected count is 0.26 and 16 cells (20%) have expected count less than 5. Therefore the Pearson Chi-Square test can be used to determine whether there is a significant relationship between the two variables type of the accident and ships' size.

The Pearson Chi-Square test statistic is 62.675. The null hypothesis (H_0) states that there is no relationship between type of the accident and ship's size. While the alternative hypothesis (H_1) states that there is a relationship between type of the accident and ships' size at the significance level at 5%. The test results indicated that the P-value (0.488) is greater than the significance level (α =0.05), hence the null hypothesis (H_0) is accepted and the alternative hypothesis (H_1) is rejected. Thus, I conclude that there is no significant statistical relationship between type of the accident and ships' size.

5 Conclusions:

Conclusively, the findings and results of this research indicates that there is significant statistical relationship between type of containerships accidents to the other indicators (factors influencing accidents) such as accident reason, zone at which the accident occurred, ships' status when the accident was occurring as well as ships age. These findings led to the suggestion of the prevention measures since it is now established by controlling each aspect of indicator means the accident type is also controlled as the result reduction accidents.

Based on the above containerships accident analysis, this study summarizes and classifies the causes of each accident in detail. Firstly, since human negligence and lack of knowledge leads to errors that are the main cause of containerships accidents, ship owners and companies should establish critical trainings and accident drills so as to enhance crew awareness on safety measures when working on board ship. Also, timely survey and inspections should be conducted so as to make sure the non-sea worthiness container ships are not allowed to sail.

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