

DATA ANALYSIS ON MARITIME ACCIDENTS OVER 1000 GRT: THE CASE OF GREECE

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ABSTRACT

According to several studies, the quantification of risk existing in maritime transportation can be estimated by using accident statistics. Analysis of accident statistics can reveal how different types of ships are susceptible to different kind of casualties. In the current paper an analysis on ship accidents is performed by using a database created from data of Ministry of Shipping and the Aegean, Directorate of Ship Safety. The database includes over 1000 recorded accident cases in ships under Greek flag, with size over 1000 grt, covering a period from 1974 to 2010. We use descriptive statistics to have an overview on main accident data. We then perform a hypothesis test to investigate the relation between the ship type variable and a) accident responsibility, b) accident outcome c) accident area. Moreover we test the relation of ship age and a total loss event. The analysis of main maritime accident variables can assist decision making and promote maritime safety.

Keywords: Greek fleet, ship accidents, total loss

Introduction

According to IMO, "Shipping is perhaps the most internationalized of Worlds' great industries and one of the most dangerous." [1]. During the last decades, ships have greatly increased in size and numbers [2]. There are several studies that for maritime safety which in some cases analyze specific ship accidents worldwide. Nowadays, maritime accidents are an important research theme.

According to Toffoli et al. by using the Lloyds world casualty statistics, the following accident categories are used :

- Grounding
- Fire/explosion
- Collision
- Wrecked/stranded
- Contact
- Hull/machinery

In the previous study, the Lloyd's Marine Information Service (LMIS) was used to create a ship casualty accident database in which 650 incidents were covered during the period from January 1995 to April 1999. The data set classified all reported accidents including total losses to all propelled sea-going merchant ships in the world for 100 gross tonnages and above. A synthesis of the main total loss causes according to frequency is given in Table 1 [3].

Table 1. Classification of ship accidents

Class	
a) Foundered	36%
b) Water ingress	25%
c) Severe hull damage	16%
d) Capsize of intact ship	8%
e) Others	15%
<i>Information referred to the research of A. Toffoli, J.M. Lefevre, E. Bitner-Gregersen, J. Monbaliu [Towards the identification of warning criteria: Analysis of a ship accident database] and collected from the Lloyd's Marine Information Service (period from January 1995 to April 1999).</i>	

Casualty records provided from NMD divide the recorded accidents into the categories of fire/explosion, grounding, heavy weather, capsizing, collision, contact, leakage, pollution/environmental damage, personnel, related, missing and other reasons [4]. The casualty records from the LRFP accident database (February 1997 to February 2007) suggested that accidents may be divided into the categories of foundered, wrecked/stranded, contact, collision, fire and explosion, missing, war loss/damage during hostilities, hull/machinery damage and miscellaneous [5].

In the current paper an analysis on ship accidents is performed using a database created from data by the Ministry of Shipping and the Aegean, Directorate of Ship Safety. This research study will try to demonstrate the differentiation of safety in respect to variables such as ship type, ship sizes, ages with a comprehensive review of this literature to aggregate different accidents factors. The used database includes 1089 recorded accident cases in ships under Greek flag. Moreover, the analysis of accident statistics shows how different ships types are susceptible to different kind of casualties. This paper will also try to record the most important initial cause of the accident, how human error is correlated to different accident types and how total loss is correlated to variables such as ship age.

2. Literature Review

According to Faulkner, there are two main sources causing ship loss and damage. About 60% of the accidents are due to operational causes (e.g. fire, collision, machinery damage), while the remaining 40% are characterized by design and maintenance causes (i.e. water ingress, hull breaking in two, and capsizing) [2]. While many incidents may be related to human errors, a number of accidents still occur due to unexpected events and dangerous sea states, which can result to an inability in keeping the ship under proper control [6]. The UK Marine Accident Investigation Branch (MAIB) states that "the factor that dominates the majority of maritime accidents is human error" [7]. Data from New Zealand are congruent with the above fact: 49% of shipping incidents cited human factors as a cause, while only 35% cite technical factors and 16% environmental factors [8].

Hetherington et al. report that the most common human causes were judgment errors and improper lookout, followed by failure to comply with regulations. The 'human element' as it is often termed in the shipping literature has frequently been cited as a cause of these costly incidents [9]. A study based on a U.S. Coast Guard report, states that between 75–96% of marine casualties are caused by some form of human error. This study mentions that 43% of accidents cite human error as the primary cause. They conclude that the actual figure of incidents involving human error may be as high as 80% [10].

During an analysis of accidents cases between 1982 and 1985, there were 2,250 cited causes, 345 of which were human error (15%) [11]. According to Heea et al. 80% or more of major marine accidents were human and organization caused. While the initial events for the majority of accident are attributed to individuals (operating personnel), the contributing causes (again more than 80%) can be attributed to the organization that influences the individual [12].

In an interesting study for the period from 1992 to 2005, 74 marine accidents of passenger ships took place in Greek waters: it is derived that about 65% of them are caused by human inadequacy. Some of the most important conclusions of this thesis are: Greek passenger ships' marine accidents covered 13% of all marine accidents of Greek flagged ships, in the period 1992 – 2005. The age of a passenger ship is not linked with the cause of a marine accident. The size of a passenger ship can be linked to the cause of a marine accident. In particular, smaller ships seem to be prone to have an accident by the inadequacy of human factor. I must be noted that 14 out of 15 passenger ships' marine accidents that had collision as first event were attributed to human factor. This is an important finding, as collision accidents were responsible for 80 deaths and 3 injuries out of 95 deaths and 78 injuries overall, in the period 1992 – 2005. Around 65% of accidents involving passenger ships in the period 1992 to 2005 were attributed to human factor. Ships aged between 21-25 years have the highest accident frequency, while an interesting observation is the reduction of the frequency of accidents for vessels of over 25 years. The age of the passenger ship is not correlated with the reason of an accident. Accidents decreased for vessels 1-10 years. The size of a passenger ships can be associated with the cause of the accident. It turns out the general trend of lower tonnage (100- 5000 GRT) to be prone to accidents involving human factors. This trend is abated gradually with the increase of the size and attains for passenger ships over 10000 GRT to be reversed, since for these ships the accident from other causes seem more likely [13].

Tzannatos analyzed the significance of the human element in accidents involving Greek-flagged ships, during 1993–2006, worldwide. It was found that 57.1% of all accidents were attributed to the human element, whereas 75.8% of the latter were detected onboard and 80.4% of the onboard human-induced accidents were linked to errors and violations of the ship's master [14]. According to the International Maritime Organization (IMO) "the human element is a complex multi-dimensional issue that affects maritime safety and marine environmental protection". According to this analysis of shipping accidents, Tzannatos found that the most frequent type of accident was that of groundings (49.6%), followed by technical failures with a significant difference of occurrence (28.7%). The other accident types (fire/explosion, collision, flooding etc) accounted for 21.6% in total and were all individually under 10%. Bulk carriers suffered most accidents (33.2%), whereas general cargo carriers, tankers and Ro-Pax entered into the accident record at around 20%.

In terms of age, the older (>27 years) and mid-aged (9–22 years) ships were involved in most accidents with 38.8% and 31.3%, respectively. The younger vessels (<9 years) suffered the least accidents (9.7%). Further analysis into the accident record revealed that although all vessel types suffered primarily from groundings, technical failures and further down fires/ explosions followed with particular significance in the case of tankers and Ro-Pax vessels. Also, the dominance of groundings was found to be irrespective of vessel age, whereas technical failures were more profound in the higher age group. These findings are related to the extent and complexity of the technologies as well as cargo/ passenger vulnerabilities present in the above mentioned vessel types, in conjunction with their increasing significance with vessel age, hence ageing failures of structure and equipment. On average, during the period 1993 to 2006, 57.1% of the investigated accidents were attributed to Human Factor, whereas Random Events, Unidentified Causes and Acts of God accounted for 31.1%, 7.9% and 3.9%, respectively. Furthermore, a significant share (78.5%) of the human element as a cause of accidents was detected onboard, whereas human causes ashore, as well as onboard and ashore (combined) covered 12.6% and 8.9%, respectively, of all the human-caused accidents.

According to these findings, both the overall and the onboard presence of the human element as a cause of shipping accidents is lower than the widely acknowledged statistics of 80% and 65%, respectively. The analysis of Greek shipping accidents during the period 1993–2006, revealed that grounding followed by technical failures dominated safety records, whereas older vessels suffered most accidents. Furthermore, despite the significant reduction of human causes after the ISM Code implementation in mid-1998, human element remains the main cause of accidents [14].

In their findings, Zobair Ibn Awal et al. proved that the leading causes of accidents were collision between ships and 80% involve cargo vehicles hitting other vehicles. It is observed from the analysis of 442 accident cases that 44% of all the accidents take place due to adverse weather condition coupled with overloading and stability problems of the vessels. It is the collision accident type that has been noted as a serious problem for Bangladesh with a very high rate of occurrence of 39% of all the accidents. Collision between ships, boats and trawlers commence from errors that originates due to both human errors and machinery faults. The predominant types of accidents in the water ways of Bangladesh are accident due to adverse weather and accident due to collision. Cargo vessels and passenger share 75% of all vehicles in collision [15].

Uğurlua et al. mentioned that tanker is a ship designed to carry liquid petroleum cargo in bulk, including a combination carrier when being used for this purpose (ICS 2006). Oil tanker means a vessel built or adopted in cargo compartments, for the purpose of transporting petroleum products, and it contains combined carriers as well. Also, chemical tankers defined in Annex-II of the MARPOL 73/78 convention are defined as oil tankers to the extent that they carry petroleum in bulk with partial or full load. The three accidents most encountered in oil tankers are, respectively, collision, grounding, and fire. The total number of collision and grounding accidents is 202. It is reported that 120 of these accidents are collisions and 82 are groundings. According to the information in the GISIS database, in 94% of the collision and grounding accidents occurring in oil tankers, the ship is lost in whole or becomes unseaworthy.

This puts forth the importance of marine accidents examined in the study. The main factor in the occurrence of collision and grounding accidents is human error. Around 77% of collision accidents and 81% of grounding accidents arise from human error [16].

Psarros et al. report that collisions, contacts, and groundings were the most frequent accidents reported in the Baltic Sea, accounting for more than half (54%) of the total number. These accidents are largely due to weather and navigation hazards as well as dense vessel traffic in the region. In addition, as mentioned earlier, many accident studies have stated that the human factor is responsible for approximately 80% of accidents, which means the other factors combined should account for 20% [17].

Goulielmos marks that out of 3,973 tanker marine accidents (1994), 248 were caused by fire and only 50,3% happened in ports or at anchor, and in ships 11-20 years of age [18]. The crucial point is that 47% of fires happened in sea areas near Europe (Northwest seas, the Baltic and the Mediterranean) and that pollution from fire is only 4 per cent [19].

A database at the University of Piraeus marked that 59,4% of accidents to Greek passenger ships occurred in ports during 1993-1997 and the main reason was contact (31,5 %) [20].

The bad years for Europe were 1988 and 1991 concerning ships total loss. Sunken ships were five to ten years of age and lost mainly by fires and explosions [21].

3. Methodology

We use a database of 1089 ship accidents between the years 1978-2010, for ships under greek flag created from data coming from the Ministry of Shipping and the Aegean, Directorate of Ship Safety. We created variables concerning ship type, ship age, accident type, accident responsibility, area of the accident and total loss-sinking.

We first use the database to have an overview of the incidents by using descriptive statistics.

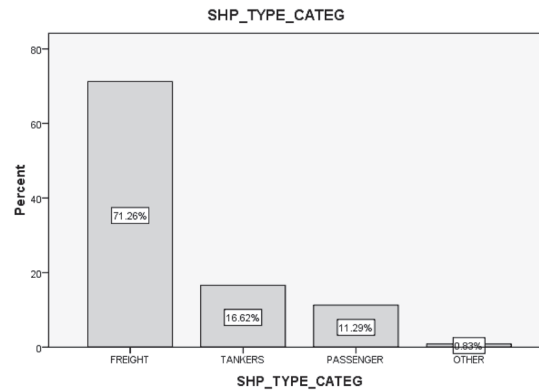
We then test the null hypotheses that: a) ship type is not related to the accident responsibility b) ship type is not related to accident outcome c) ship type is not related to area of the accident and d) ship age is not related to total loss-sinking of the ship. The hypothesis tests are performed by the pearson chi-square test and the crosstab command in SPSS.

4. Results

Descriptives

We firstly use descriptive statistics to have a complete overview of the Greek fleet accident situation. The graphs provide information for 1084 accidents between the years 1974 to 2010, for ships over 1000 gross registered tonnage (hence after GRT). Accidents are presented in bar charts (each bar represents percentage of total accidents) according to ship type, ship size, ship age, area of the accident, accident outcome and accident responsibility.

Figure 1. Greek maritime accidents classified per ship type (1974-2010)



Based on figure 1 which categorizes accidents by ship type, we observe that 71.6% of accidents are associated to freight ships, 16.62% are associated to tankers, 11,29% are passenger ships and a rate of 0,83% includes other ship types. This is consistent with the synthesis of the Greek fleet.

Figure 2. Greek maritime accidents classified per ship size

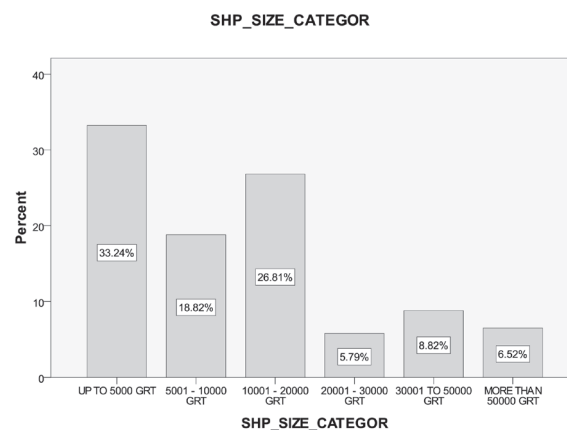


Figure 2 shows accidents classification according to vessels size (in gross registered tonnage). Specifically, we observe that 33.24% refers to accidents for ships that are up to 5000 GRT, 18.82% of ships size 5001-10000 GRT, 26,81% are between 10001-20000 GRT and 5.79% are 20001-30000 GRT while the other 8.82% includes vessels between 30001-50000 GRT. Finally a rate of 6,52% is attributed to ships with size more than 50000 GRT.

Figure 3. Greek maritime accidents classified per ship age

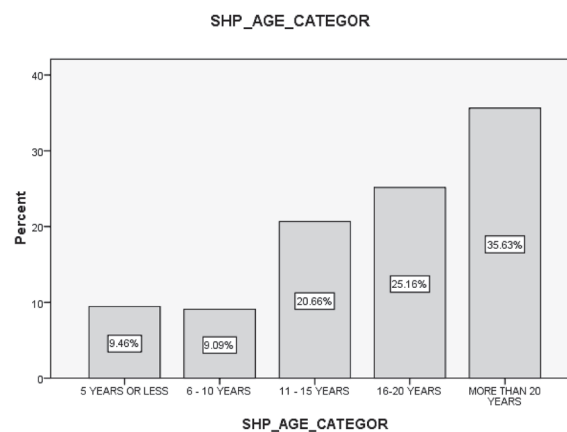


Figure 3 indicates the age of the ships that are recorded with respect to accident frequency. We observe an almost linear association between ship age and accident frequency. In particular, we note that the highest percentage of 35.63% includes vessels with age more than 20 years, while ships between 16-20 years have a percentage of 25.16%. Accordingly 20.66% is for vessels 11-15 years, 9.09% is for 6-10 years and finally a rate of 9.46% represents ships of 5 years or less.

Figure 4. Greek maritime accidents classified per accident outcome

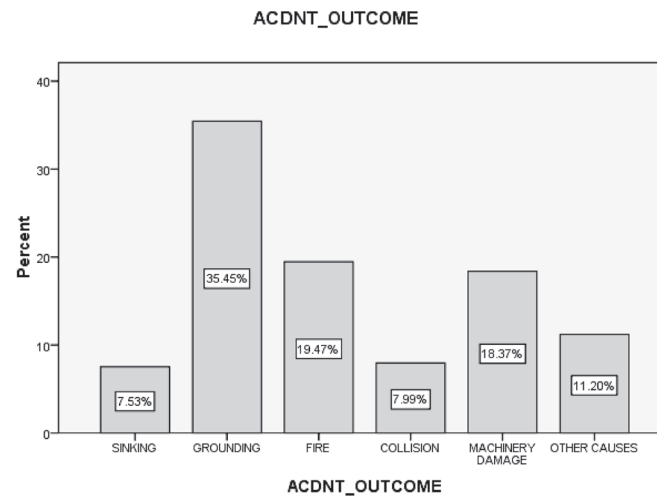


Diagram 4 shows the results for the accident outcome. Starting from lowest, first accident outcome is sinking by 7.53%, collision distracts 7.99%, other causes 11,20%, machinery damage owns a rate of 18.37%, accidents caused from fire 19,47% and finally grounding distracts 35.45%. As we can see by the percentages presented, grounding is responsible for the largest proportion of accidents while fire and machinery damages are equally responsible with significant percentages.

Figure 5. Greek maritime accidents classified per accident area

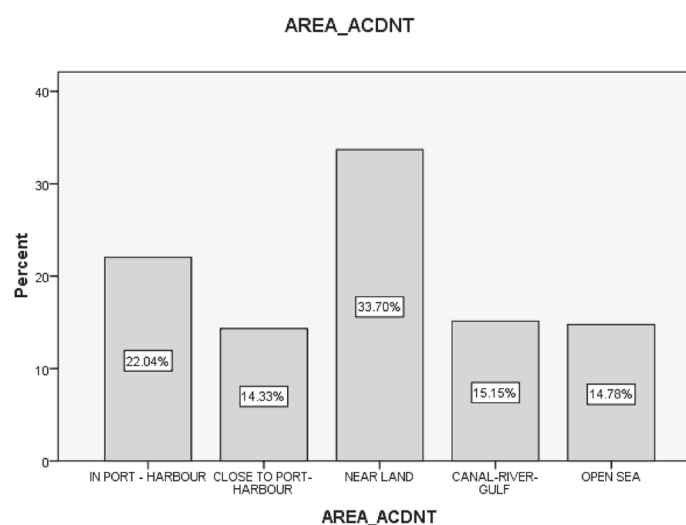
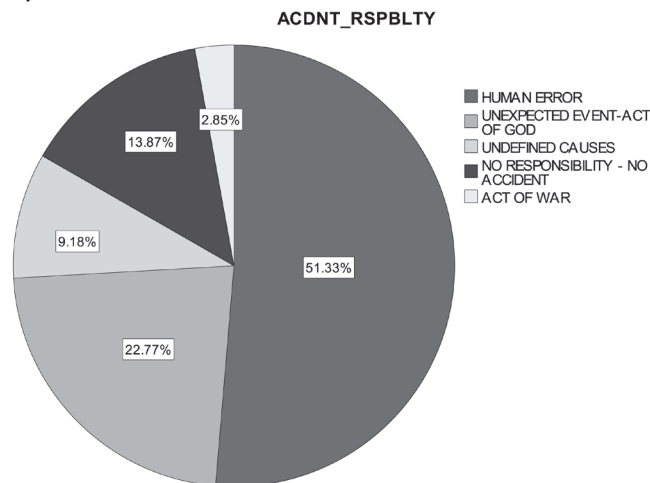


Figure 5 refers to the areas where accidents took place. Starting with the area that possess the highest rate, near land accidents have 33.70%, port-harbour include 22,04%, close to port-harbour have 14.33%, canal-river-gulf with 15.15% and finally the open sea with 14.78%.

Figure 6. Accident responsibility



In the last figure, categories refer to accident responsibility. As we observe human error has the highest percentage (51.33%) and is the main reason for accidents that occurring to ships. Including 22.77% is the unexpected event-act of God, 13,87% is the no responsibility-no accident, fourth with a smaller percentage is undefined causes with 9.18% and fifth with even smaller percentage is act of war with 2.85%.

Hypothesis tests

We will use our database to test the null hypothesis that ship type is not related to accident responsibility. The relation between ship type and accident responsibility is shown in table 2.

Table 2. Crosstabulation between ship type category and accident responsibility

SHP_TYPE_CATEG * ACDNT_RSPBLTY Crosstabulation

			ACDNT_RSPBLTY					Total
			HUMAN ERROR	UNEXPECTED EVENT-ACT OF GOD	UNDEFINED CAUSES	NO RESPONSIBILITY - NO ACCIDENT	ACT OF WAR	
SHP_TYPE_CATEG	FREIGHT	Count	392	185	71	116	12	776
		Expected Count	398.3	176.7	71.3	107.6	22.1	776.0
	TANKERS	Count	94	33	13	23	18	181
		Expected Count	92.9	41.2	16.6	25.1	5.2	181.0
	PASSENGER	Count	68	29	14	12	0	123
		Expected Count	63.1	28.0	11.3	17.1	3.5	123.0
	OTHER	Count	5	1	2	0	1	9
		Expected Count	4.6	2.0	.8	1.2	.3	9.0
	Total	Count	559	248	100	151	31	1089
		Expected Count	559.0	248.0	100.0	151.0	31.0	1089.0

Table 3. Chi-Square Test between Ship type category and accident responsibility

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	52.105 ^a	12	.000
Likelihood Ratio	44.094	12	.000
Linear-by-Linear Association	.257	1	.612
N of Valid Cases	1089		

a. 6 cells (30.0%) have expected count less than 5. The minimum expected count is .26.

By looking at the Pearson chi-square index on table 3 ($p=0.00<0.05$), the null hypothesis is rejected meaning that the variables of accident type and ship type are related. This means that different ship types are more susceptible to specific accident reasons. If we look at the cross tabulation table we notice that for the “human error”, the observed count is more than expected for tankers and passenger ships, meaning that this attribute is more likely for those two types. On the other hand human error is less than expected for freight ships. For freight ships the “act of god event” category has showed up more times than expected, if the variables were not correlated. In the case of tankers the “act of war” observed count is more than expected, meaning that this category of ships is more susceptible to accidents due to war acts.

We continue our analysis by checking the null hypothesis that accident outcome is not related to ship type. Accident classification according to ship type and accident outcome is presented in table 4.

Table 4. Crosstabulation between ship type category and accident outcome

SHP_TYPE_CATEG * ACDNT_OUTCOME Crosstabulation									
			ACDNT_OUTCOME						Total
			SINKING	GROUNDING	FIRE	COLLISION	MACHINERY DAMAGE	OTHER CAUSES	
SHP_TYPE_CATEG	FREIGHT	Count	68	277	143	55	170	63	776
		Expected Count	58.4	275.1	151.1	62.0	142.5	86.9	776.0
	TANKERS	Count	4	68	37	11	20	41	181
		Expected Count	13.6	64.2	35.2	14.5	33.2	20.3	181.0
	PASSENGER	Count	10	39	29	20	9	16	123
		Expected Count	9.3	43.6	23.9	9.8	22.6	13.8	123.0
	OTHER	Count	0	2	3	1	1	2	9
		Expected Count	.7	3.2	1.8	.7	1.7	1.0	9.0
	Total	Count	82	386	212	87	200	122	1089
		Expected Count	82.0	386.0	212.0	87.0	200.0	122.0	1089.0

Table 5. Chi-Square Test between ship type category and accident outcome

Chi-Square Tests			
	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	73.123 ^a	15	.000
Likelihood Ratio	72.506	15	.000
Linear-by-Linear Association	1.606	1	.205
N of Valid Cases	1089		

a. 6 cells (25.0%) have expected count less than 5. The minimum expected count is .68.

As we observe from the chi-square test of table 5, the null hypothesis is rejected meaning that different ship types are more susceptible to certain accident types. By looking at table 4 we notice that freight ships have more counts than expected for the categories of sinking and machinery damage. Tankers on the other hand are less susceptible to sinking than expected but are prone to groundings and other events. Passenger ships are prone to fire and collisions, compared to other ship types.

In order to test the relation between ship type and accident area, we test the null hypothesis that ship type is not related to accident area.

Table 6. Crosstabulation between ship type category and area accident

SHP_TYPE_CATEG * AREA_ACDNT Crosstabulation								
			AREA_ACDNT					Total
			IN PORT - HARBOUR	CLOSE TO PORT - HARBOUR	NEAR LAND	CANAL - RIVER - GULF	OPEN SEA	
SHP_TYPE_CATEG	FREIGHT	Count	159	106	270	131	110	776
		Expected Count	171.0	111.2	261.5	117.6	114.7	776.0
	TANKERS	Count	39	34	54	20	34	181
		Expected Count	39.9	25.9	61.0	27.4	26.8	181.0
	PASSENGER	Count	40	15	40	13	15	123
		Expected Count	27.1	17.6	41.5	18.6	18.2	123.0
	OTHER	Count	2	1	3	1	2	9
		Expected Count	2.0	1.3	3.0	1.4	1.3	9.0
	Total	Count	240	156	367	165	161	1089
		Expected Count	240.0	156.0	367.0	165.0	161.0	1089.0

Table 7. Chi-Square Test between variables ship type and accident area

Chi-Square Tests			
	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	19.725 ^a	12	.072
Likelihood Ratio	18.995	12	.089
Linear-by-Linear Association	4.391	1	.036
N of Valid Cases	1089		

a. 5 cells (25.0%) have expected count less than 5. The minimum expected count is 1.29.

By looking at the chi-square on table 7 we see that the null hypothesis is rejected at the 90% level, meaning that certain ship types have more accidents in certain areas. For the case of passenger ships, we counted 40 accidents inside a port-harbour while the expected count is 27, meaning that those ships have more accidents inside a harbour. The opposite stands for the other ship types, especially freight ships which have fewer accidents inside harbours than expected but have more accidents near land and in gulf, canals and rivers. Tankers on the other hand have more accidents than expected in the open sea.

Finally we seek if age of the ship is related to a total loss (sink) incident. The results of table 8 reveal that ships between 16-20 years old are more susceptible to sinking than other ship types. This can be verified by the Pearson Chi-Square test on table 9 which verifies the relation of the two variables, total loss and ship age.

Table 8. Crosstabulation between ship age category and total loss

SHP_AGE_CATEGOR * TOT_LOSS Crosstabulation					
			TOT_LOSS		Total
			NO TOTAL LOSS	TOTAL LOSS	
SHP_AGE_CATEGOR	5 YEARS OR LESS	Count	99	4	103
		Expected Count	94.6	8.4	103.0
	6 - 10 YEARS	Count	96	3	99
		Expected Count	90.9	8.1	99.0
	11 - 15 YEARS	Count	206	19	225
		Expected Count	206.6	18.4	225.0
	16-20 YEARS	Count	243	31	274
		Expected Count	251.6	22.4	274.0
	MORE THAN 20 YEARS	Count	356	32	388
		Expected Count	356.3	31.7	388.0
	Total	Count	1000	89	1089
		Expected Count	1000.0	89.0	1089.0

Table 9. Chi-Square Test between variables ship age category and total loss

Chi-Square Tests			
	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	9.641 ^a	4	.047
Likelihood Ratio	10.869	4	.028
Linear-by-Linear Association	3.892	1	.049
N of Valid Cases	1089		

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 8.09.

Conclusions

An analysis of 1089 Greek maritime accident cases was performed, by using data for the period 1974 -2010. The main findings of this study are the following: Ships of capacity under 5000 grt are more prone to accidents since they consist 1/3 of total accident events. We recorded a positive linear relation between ship age and accident frequency. Around 35% of total incidents happened to ships aging over 20 years. Concerning accident outcome, the most usual accident event is grounding, recorded in 35% of total accidents, followed by fire and machinery damage. About accident area it was found that 33% of total accident occurred near land and around 22% inside harbours. Only around 15% of total accidents happened in open sea. Concerning accident responsibility, around half of the accidents involved human error while only 23% were attributed to unexpected events. Hypothesis test between the variables of ship type and accident responsibility revealed a relation between the two variables. By using the chi square index and comparing observed and expected count on the crosstabulation tables, it was found that human error happens more than expected for passenger ships and tanker ships. On the other hand, unexpected events occur more than expected in freight ships. Concerning the relation of ship type and accident outcome, we noticed that passenger ships are prone to fire and collisions, freight ships are prone to sinking and machinery damage and tankers are less prone to sinking but more prone to groundings. Concerning the accident area, passenger ships were found to have more accidents inside ports while freight ships have more accidents near land or inside rivers and canals. It was found that tankers have more accidents in open sea. Concerning the event of a total loss of a ship, hypothesis test shows a relation to ship age. Specifically ships between 16-20 years were found to have more ship losses than expected. Younger ships at the other have less losses than expected. Our results are consistent with papers reviewed in this article. As further research we believe that a binary logistic regression model for the estimation of a total loss event, would lead to a further understanding of the contribution of specific database variables to the accident event. Accident analysis can assist maritime community to address the most important factors contributing to accidents and promotes maritime safety.

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