Accidents in Greek Coastal Shipping: Human Factor and Old Ships…or maybe Small Ships?

I.C. Gemelos[1], N.P. Ventikos[2]

Laboratory for Maritime Transport

Division of Ship Design and Maritime Transport

Department of Naval Architecture and Marine Engineering

National Technical University of Athens

E-mail: [1]giannis_g1@yahoo.com
[2]niven@deslab.ntua.gr

Abstract

The comprehensive analysis presented in this paper investigates the links and comparative assets between human factor and other factors that are important determinants of maritime transport risk. In this outline, the identification of factors, such as age and ship size, that can be statistically linked (i.e. statistical significance) to whether an accident in a passenger vessel can be attributed to human factor or other causes is addressed accordingly. This way, the role of human factor in relation to safety of Greek coastal shipping is revealed and the spotlight is able to focus on the various aspects and points that manifest the importance of human element in the maritime industry. According to the knowledge of the authors of this paper, this is the first extensive hypothesis analysis that it implemented in the human element and its role within the shipping industry. The paper is concluded with interesting insights and comments drafted through the aforementioned tasks.

Key words: human factor; marine accident; coastal shipping; marine safety; human reliability; statistical significant.

1. Introduction: The Problem

The most important concern in the maritime field is the safety of ships at sea. The improvement of marine safety, as the total assurance is something unattainable, is always a target for all involved stakeholders. The concern augments in the case of passenger ships that carry thousands of lives; Greece is a typical example of this problem since it has a large coastline and dozens of islands with Greek passenger ships transferring up to 50,000,000 people every year. Greek passenger ships cover the 28% of the total Greek merchant fleet (Statistical Service of the Hellenic Ministry of Mercantile Marine). This percentage is quite large but reasonable due to the necessity of increased coastal shipping, so as to be able to connect the great amount of Greek islands with the ports of the country. The importance of this percentage is getting even bigger, if someone mentions that – worldwide – passenger ships cover less than the 10% of the overall fleet (European Maritime Safety Agency (EMSA) and Equasis Statistics, 2005).

In a period of 14 years – from 1992 to 2005 – 74 marine accidents of Greek passenger ships took place: it is derived that about 65% of them are caused by the inadequacy of immediate human factor (Safety of Navigation Directorate of Hellenic Ministry of Mercantile Marine). The fact that this percentage is lower than the one that is referred to all marine accidents worldwide (75-96% by human factor's negligence (Rothblum, 2002)) is not reassuring at all. It has been deemed more than sure that the use of more and more advanced and reliable equipment will decrease the percentage of accidents caused by technical and machinery problems, increasing step-by-step the percentage of accidents caused by human factor.

The scope of this paper is to put emphasis on the important and multilevel role of human factor in the safety of Greek coastal shipping. The identification of factors, such as age and ship size, that can be statistically linked to whether an accident of a passenger vessel can be attributed to human factor or other causes will be addressed accordingly. An analysis of statistical significance will generally not prove a cause-and-effect relationship, but it will reveal whether variations in accident rate are systematic or are due to chance alone. The risk assessment of Greek passenger ships is implemented so as to put forth the safety level and records of Greek coastal shipping.

The most important thing, when an accident occurs, is the consequences. Especially, in the case of passenger ships the consequences are measured with injuries and loss of lives. In the period from 1992 to 2005, 95 people lost their lives and 78 got injured in Greek passenger ships' accidents, with the accident of Express Samina to play a prominent role in this unpleasant counting. This marine accident – in September, 2000 – has attracted the attention of the public opinion by costing the life of 80 people. Moreover, it is important to be mentioned that 93% of Greek passenger ships' accidents that led in an injury or death and 85% of deaths – in these 14 years – were caused by human factor inadequacy.

The assessment of the individual values of risk for the accidents caused by human factor or other causes, respectively, is an innovative way in order for the unbreakable relation of marine accidents of Greek passenger ships and their results, with human factor to be identified clearly. A typical example comes from the comparison of the values of the Fatality Ratio (= No. of fatalities / No. of casualties) for the marine accidents of Greek passenger ships caused by human factor or other causes. The value of the Fatality Ratio for the accidents involving human factor is almost 3.4 times bigger than the one for the accidents from other causes.

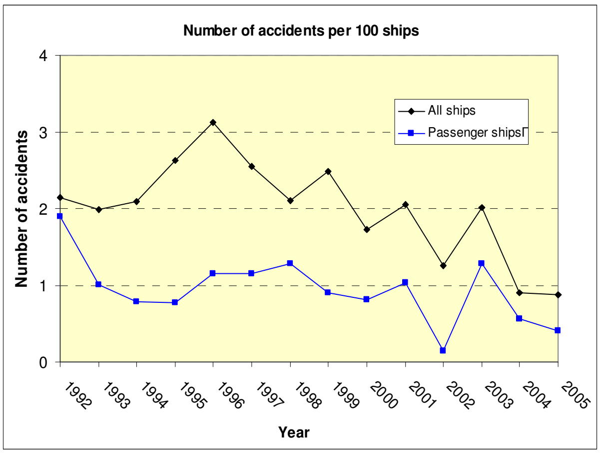


Figure 1: Frequency of accidents per 100 ships for the total Greek fleet and Greek passenger ships, 1992 – 2005

Figure 1 shows the frequency of accidents per 100 ships for the entire Greek merchant fleet and Greek passenger ships, respectively. Despite the inconstancy and the fluctuations, it is obvious a decreasing trend after 1996, in terms the marine accidents for the total fleet. On the contrary, the trend of the frequency of passenger ships' accidents is far from being reckoned as decreasing. This observation is also confirmed by Kendall's tau test, which is indicative of a significant downward trend for the frequency of accidents of the whole Greek fleet (τ = -0.516, p = 0.010), but no temporal trend for the frequency of passenger ships' accidents (τ = -0.319, p = 0.112). It has to been noticed that the drastic reduction of the marine accidents in the last two years (2004–2005) can be deemed, in some degree, unsubstantial. The main reason for that is the fact that it is a common phenomenon to there is a delay in the completion of the list. It takes sometimes a couple of months or years for the final inference.

To conclude this section, it is interesting to view the mapping of human error in relation to the main compartments of the ship (**Figure 2**). In most marine accidents (76%) due to human negligence, the starting point of human error was the bridge of ship. Accidents due to human error in the engine room cover 17% of the total respective number of accidents, and the rest 7% concerns accidents that started somewhere else on board the ship (e.g. galley), and they are usually fires and/or explosions.

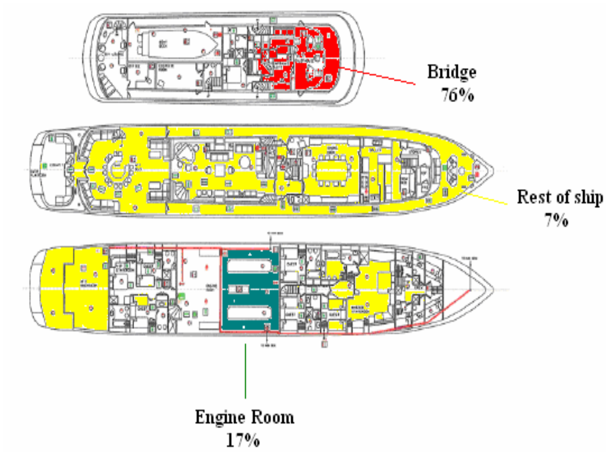


Figure 2: Mapping of human error on board ships

The rest of the paper is structured as follows: the next Section refers to the human factor and the important role that has in relation to on board safety. The following one presents the sources of the data and then a brief presentation of the statistical tests that were used for the analysis is made. The main part of the paper – which covers the results of the analysis – is shown thoroughly in two Sections. This paper is concluded with a short yet interesting discussion regarding the findings and insights from the aforementioned Sections.

2. Human Factor, the Cause

Human factors refer to environmental, organizational and job factors, and human and individual characteristics that influence behavior at work in a way that can affect health and safety (HSE, 1999). It includes consideration of:

- The job tasks should be designed in accordance with ergonomic principles to achieve a physical and mental match with people's capabilities.
- The individual – people should be recruited and trained so that they are competent in performing the job.
- The organization – the company should establish a positive health and safety culture (DNV, 2001).

It has been estimated that up to 90% of all workplace accidents have human factor as a cause (Feyer & Williamson, 1998). Human error was a factor in almost all the highly publicized accidents in recent memory, including Chernobyl incident, Hillsborough football stadium disaster and others (Parliamentary office of Science and Technology, 2001). Marine industry could not stay unaffected by this factor and the numbers indicate the hard reality: over 80% of marine casualties are caused, at least in part, by some form of human error (IMO, 1999).

Chairman Jim Hall (2000) of the National Transportation Safety Board (NTSB) has said that accidents can be viewed as very successful events. By using the word "successful", he intended to emphasize that it is actually difficult to create an accident. Accidents are not usually caused by a single failure or mistake, but by the confluence of a whole series, or chain, of errors (Rothblum, 2002). In looking at how accidents happen, it is usually possible to trace the development of an accident through a number of discrete events. The above can be plotted very effective by the – pretty much – well known "*Swiss cheese model of accident causation*".

Figure 3 shows a trajectory of accident opportunities and its penetration through several types of defensive system. The combined chances/probabilities leading to an accident occurrence are very small; hence the holes in the various defence systems must all line up and provide the path for a "complete" failure. In effect, some are active failures of human or mechanical performance, and others are latent conditions, such as management factors or poor system design. However, it is clear that if steps are taken in each case to reduce the defensive gaps, the overall chance of accident will be greatly reduced. Organizational planning can reduce the latent failures at the managerial level, psychological failings can be reduced by paying attention to the types of task that are required of workers and unsafe acts can be reduced by good interface design (Reason, 2000).

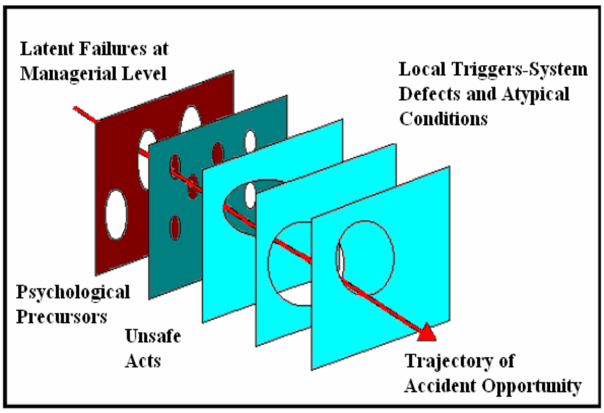


Figure 3: The Swiss cheese model of accident causation

A fair explanation of the huge negative contribution of human factor in the generation of accidents – in relation to all industries, including the maritime one – is the delay in dealing with this very serious factor. Reason (1990) interprets the development of interest in the human contribution to accidents in terms of three ages of safety concerns (**Figure 4**). First, the focus was on technical problems, and this still has its place, e.g. the human driven accident of Exxon Valdez led to the introduction of double hull tankers, the organizational fiasco of the Prestige case accelerated the phase out of the single hull tankers, etc. However, as technical systems became more reliable, the focus turned to the human causes, and many accidents were blamed on individuals directly involved in the operation. More recently, major accidents investigations have recognized that the root causes of failures of equipment and operators lie deeper in the organization's safety management and safety culture (DNV, 2002).

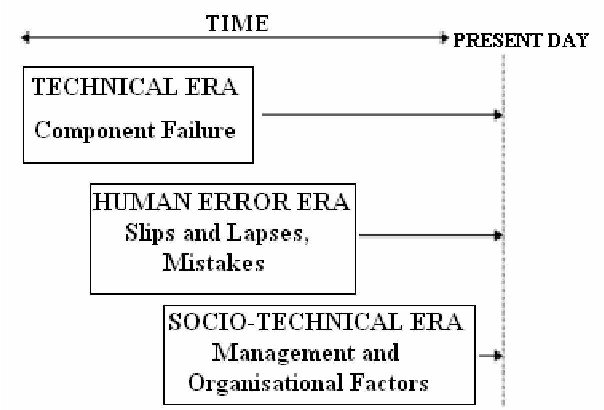


Figure 4: Three Ages of Safety Concerns

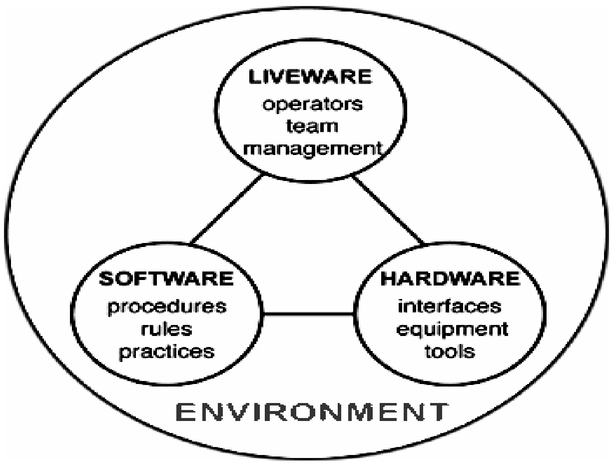


Figure 5: The SHEL model

However, this cannot be an excuse for the huge percentages of human factor as a cause in marine accidents. Besides that, the delay in dealing with this so important factor is not the primary reason for the catastrophic consequences that, usually, follow an accident by human factor's inadequacy. The main point is that maritime system is a *peopl*e system. People interact with technology, the environment, and organizational factors. Sometimes the weak link is with the people themselves; but more often the weak link is the way that technological, environmental, or organizational factors influence the way people perform (Rothblum, 2002). In a complex, interactive and well-guarded transportation system such as the maritime industry, accidents rarely originate from actions or non-actions of the front-line operators alone; accidents are a result of the combination of failures or deficiencies in organizational policy and procedures, human actions, and equipment (Cox and Tait, 1991). The SHEL model

(**Figure 5**) is often used to describe systems as consisting of the Hardware and Software as well as the Liveware – the human operator(s) – and the environment. This model is particularly useful since it emphasizes the interfaces between the different components of a human-machine system (IMO, 2000).

The performance of humans in a working environment is dependent on many traits, both innate and learned. So it is very important, human being's capabilities and limitations to be understood. The most important of them are:

♦ Attention – the modern workplace can "overload" human attention with enormous amounts of information, far in excess of that encountered in the natural world.
♦ Perception – in order to interact safely with the world, the dangers, that it holds, must be correctly perceived. Work environments often challenge human perception systems and information can be misinterpreted.
♦ Memory – people's capacity for remembering things and the methods they impose upon themselves to access information often put undue pressure on them. Increasing knowledge about a subject or process allows them to retain more information relating to it.
♦ Logical reasoning – failures in reasoning and decision making can have severe implications for complex systems. Human beings are not very good at thinking logically, but in technological situations, logical procedures are often necessary (Parliamentary office of Science and Technology, 2001).

3. Database Description: The Data

Due to the statistical nature and focus of this paper, reliable data on marine accidents were required. The data should be in a form allowing the investigation of possible correlation between the cause of accidents and a number of factors such as the age and the size of ship; the results and the trends from such an effort can be extremely revealing with regards to the enhancement of the safety of the maritime industry.

The main source that it was used for the research and analysis of this paper was the marine accident records collected by the Hellenic Ministry of Mercantile Marine and, in particular, the list that composed by the *"Safety of Navigation Directorate"* for the period 1992–2005. This list contains all the cases of Greek flagged ships' accidents involving ships of 100GT or more, and the high-level data categories that provides are:

- SHIP NAME
- SHIP'S REGISTER NUMBER
- SHIP TYPE
- YEAR BUILT
- GROSS TONNAGE (GT).
  Data was restricted to vessels over 100 GT.
- DATE OF ACCIDENT
- AREA OF ACCIDENT
- TYPE OF ACCIDENT :
  Each marine accident can be described by a series of distinct events that take place in a specific order. In effect, TYPE OF ACCIDENT refers to the first such event in chronological order. The accidents are grouped into the following groupings:
    - Collision / Allision
    - Grounding
    - Fire / Explosion
    - Component failure (Non accident structural failure)
- CAUSE OF ACCIDENT :
    - Human factor
    - Other causes: The characterization "other reasons" concerns the marine accidents that, according to the official inference, are attributed in untraceable reasons or in incidental case or in force majeure.
- RESULT OF ACCIDENT
  There are no categories here, as the variable is of rather descriptive nature.
- LOSS OF LIVES – INJURIES
- INVESTIGATION'S INFERENCE OF *"INTERROGATION COUNCIL OF MARINE ACCIDENTS"*

"Interrogation Council of Marine Accidents" is specialized to conduct the inquiry for every marine accident and, then, to compose the respective report about the causes of the accident. It comprises by Coast Guard officers, engineers, lawyers, etc. and it comes under Hellenic Ministry of Mercantile Marine. The investigative process can be a long one, as it involves depositions under oath of all personnel involved in each accident, the possible use of specialists to ascertain technical matters, and the writing of a report that not only offers the Ministry's official view of what may have occurred, but also assigns civil or even criminal responsibilities to people in the event they prove responsible for the accident (Psaraftis et.al., 1998).

From the final list of *"Safety of Navigation Directorate"*, only passenger ships' accidents were chosen – eliminating all the other ship types' accidents, including leisure cruisers, yachts and catamarans. The final list contained 74 cases of passenger ships' accidents, a number that can be regarded as sufficient for the implemented research and statistical analysis. Moreover, the Statistical Service of the Hellenic Ministry of Mercantile Marine was a helpful source for the gathering of further important data about the Greek merchant fleet and the number of passengers that boarded Greek passenger ships in the period 1992-2005.

4. Analysis: The Tools

Statistics and in particular statistical tests were the spearhead of the try to identify a prospective link between the cause of an accident and other important factors, such as ship age and size; they have been proved to play an important role in the safety of ships at sea. Statistics was also a helpful manner to be investigated whether and in which level some age and size categories of the passenger ships seem to be more prone to be involved in a marine accident caused by human factor than others.

A statistical significance test provides a mechanism for making quantitative decisions about a process or processes. The intent is to determine whether there is enough evidence to reject a conjecture or hypothesis about the process. This hypothesis that it is tested if it can be rejected is called the null hypothesis (H_0). There is another hypothesis, alternative hypothesis (H_1), which is complementary to the null hypothesis; therefore, only one of the two hypotheses can be true or accepted. For example, if the goal is to see if a new language model performs significantly better than a baseline language model, the null hypothesis would be both language models performs similar – as we want to find a strong clue which says two language models perform differently.

The test procedure is then constructed so that the risk or the probability of rejecting the null hypothesis, when it is in fact true, is small. This risk, α, is often referred to as the significance level of the test. By designing a test with a small value of α, it can be ensured that rejecting the null hypothesis is meaningful. Next, based on a sample statistic, the probability of obtaining the test statistic greater than or equal to the observed sample statistic is estimated under the null hypothesis: p-value. Finally, if the probability, p-value, is smaller than the significance level α, it means that it is extremely unlikely that the sample statistic happens under the null hypothesis, and thus, the null hypothesis is rejected; otherwise, as there is no strong evidence that it does not happen, the null hypothesis is accepted(Kim, 2004).

In order to investigate whether the probability of having an accident caused by human factor is influenced by ship age and size, data on the composition of the Greek fleet was required. A series of statistical tests had to be employed to check whether statistically significant dependence exists between the variables "human factor/other causes" and the ship age and size.

The "chi-square" test was selected to statistically check the null hypothesis that the two variables are independent, due to its "goodness-of-fit" properties. The null hypothesis is rejected when $\chi^{2*} > \chi^2_{\alpha,v}$, where χ^{2*} is the sample value calculated with equation:

$$X^2 = \sum_{i=1}^{k} \frac{(O_i - E_i)^2}{E_i} \qquad (1)$$

where O_i is the observed number of items in category i and E_i is the expected number of items in category i if the null hypothesis is true, and $\chi^2_{\alpha,v}$ is the critical value for the particular level of significance α and degrees of freedom v (Bernstein R. & Bernstein S., 2000). According to the standard method, a p-value of the χ^2 is calculated. In case that the p-value is above 0.05, the null hypothesis is accepted as statistically significant at the 95% level. In the opposite case (p-value below 0.05) the null hypothesis is rejected, signaling statistically significant dependency between the two variables (Rowntree, 1981).

The chi-square goodness-of-fit evaluates whether the distribution of frequencies within k categories of a single variable is the same as in a theoretical distribution. In other words, goodness-of-fit statistic reports a measure of the deviation of the fitted (theoretical) distribution from the empirical one. The smaller the fit statistic test value is (and, necessarily smaller than the critical value), the better the fit (Bernstein R. & Bernstein S., 2000). How likely is it that the theoretical distribution fits the empirical one? This probability is referred to as the p-value and it is sometimes called the "observed significance level" of the test. As the p-value decreases to zero, it is less and less accurate that the fitted distribution could possibly have generated the original data set. Conversely, as the p-value approaches one, there is no basis to reject the hypothesis that the fitted distribution actually generated the data set.

Ages and sizes of passenger ships that were involved in a casualty were examined for differences between accident's causes (human factor and other causes) using Student's t-test, which allows to test hypotheses about differences between two means (i.e. groups of samples) by comparing variances. The key statistic in Student's T-test is the t-test of difference of group means that is calculated as the ratio of two estimates of variance, i.e. the between group variation divided by the within group variation. If the calculated t-value exceeds the theoretical value of the t-distribution at a chosen level of significance (α), then one can reject the null hypothesis (H_0) and conclude that variances are significantly different. However in most cases a p-value is calculated, which is a measure for the evidence against H_0; thus the decision rule becomes "reject H_0 if p-value is less that α" (Rice, 1989).

The Wilcoxon Signed-Rank test determine whether the population median is equal to a hypothesized value (H_0: $\mu = \mu_0$). It is based on the definition of the median: if the median is as hypothesized, then half the sample values will be above and half will be below the hypothesized value. The test statistic then operates on the difference scores, which are obtained by subtracting the hypothesized median from the observed values (Bernstein R. & Bernstein S., 2000).

The Mann-Whitney U test (or the Wilcoxon-Mann-Whitney test) is a rank-order, nonparametric hypothesis test for determining whether two independent samples come from the same population. It is a rank-sums test for ordinal-level measurements that assumes the two samples are independent and come from populations with continuous distributions. The null hypothesis is that the distributions of the two populations, from which the samples were taken, are the same (Bernstein R. & Bernstein S., 2000). Both in the Wilcoxon Signed-Rank test and the Mann-Whitney U test, the key factor is the p-value. In case that the p-value is above 0.05, the null hypothesis is accepted as statistically significant at the 95% level. If the p-value is below 0.05, the null hypothesis is rejected.

The odds ratio is a way of comparing whether the probability of a certain event is the same for two groups. For example, it can be compared if it is equally likely to have an accident by human factor (event) for a passenger ship under 10 years old (first group) or over 10 years old (second group). An odds ratio of 1 implies that the event is equally likely in both groups. An odds ratio greater than one implies that the event is more likely in the first group. An odds ratio less than one implies that the event is less likely in the first group (Miller, 2005). In order to interpret the odds ratio, the calculation of a confidence interval is necessary. The tendency that is indicated by the values of odds ratio can be said as statistical significant, if the odds ratio is greater than one and the lower bound of the confidence interval does not go below 1, or if the odds ratio is lower than one and the upper bound of the confidence interval does not go above 1, respectively.

Trend analyses were calculated using Kendall's tau (τ) because it has some advantages over the Spearman coefficient R, particularly when data are tied. Additionally, when data are limited to only few discrete values, Kendall's tau is also considered a more suitable statistic. The Kendall tau rank correlation coefficient (or simply the Kendall tau coefficient, Kendall's τ or Tau test(s)) is used to measure the degree of correspondence between two rankings and assessing the significance of this correspondence. In other words, it measures the strength of association of the cross tabulations (Conover, 1999). Results of Kendall's tau reported in the following form: τ = Kendall's tau correlation coefficient and p = p-value.

5. Results: Age of Ship and Human Factor

The age of Greek fleet and, especially, that of passenger ships was always a main topic in the dialogue among ship owners, the Hellenic Ministry of Mercantile Marine and, mainly, the society. The pressure of public opinion for the withdrawal of *"rust buckets"* – a trademark for the low quality, poorly maintenanced vessels – is getting even bigger in the aftermath of major accidents such as the allision of Express Samina, in 2000.

As it is shown in **Figure 6**, the passenger ships from 21 to 25 years old seem to be more prone to be involved in a marine accident. On the other hand, the ones with ship age from the 11 – 15 category exhibit the lowest risk. A very important remark is that the accident frequencies steadily reduce with ship age from the 21 – 25 category to 31 – 35 one. A logical explanation can be the fact that it is most likely that the structural and mechanical deficiencies of a ship would have surfaced by the time it reaches her 25th year of age (Psaraftis et al., 1998).

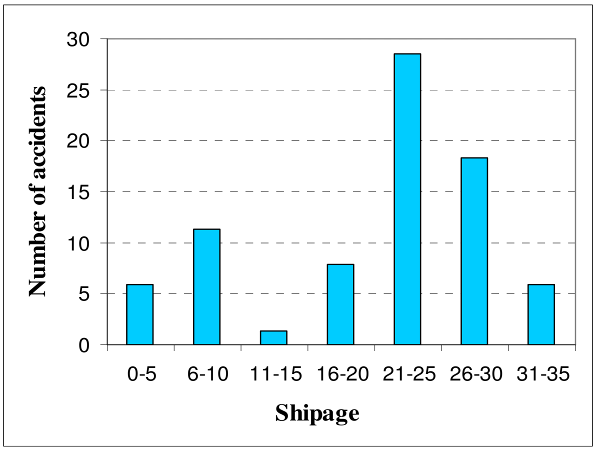


Figure 6: Distribution of accidents per 100 passenger ships by ship age, 1992 – 2005

The comment above constitutes a very serious indication that the enforcement of age limit for passenger ships is not a panacea for the improvement of coastal shipping safety. Moreover, the persistent reference to this issue – especially in the aftermath of marine accidents older ships, like Express Samina – inhibits the real and more dangerous threats of marine safety from exposure. From this point of view, the decision of the Hellenic Ministry of Mercantile Marine to phase out the age limit from Greek coastal shipping, harmonizing its legislation with the Stockholm Treaty (June 2002), can be characterized as correct.

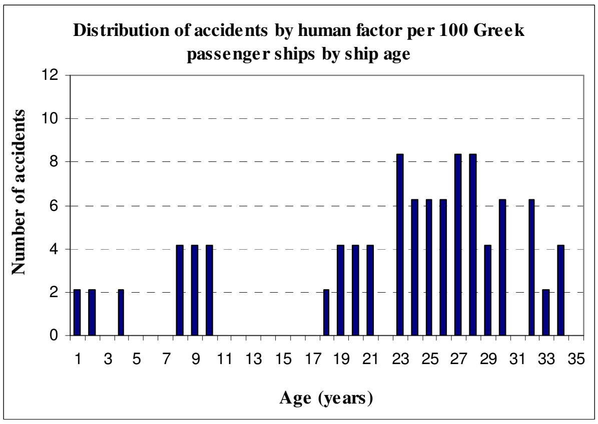


Figure 7: Age distribution of accidents by human factor per 100 Greek passenger ships by ship age illustrated with a histogram, 1992 – 2005

The comparison between the age distribution of passenger ships that had a marine accident caused by human factor with the one of the accidents that are attributed to other causes, is a good starting point for the examination of the link between age of ship and cause of marine accident. As shown in **Figure 7**, it is obvious that the accident frequencies are higher for the older ships. In particular, 81% of the total number of accidents caused by human factor was recorded in passenger ships 18-35 years old.

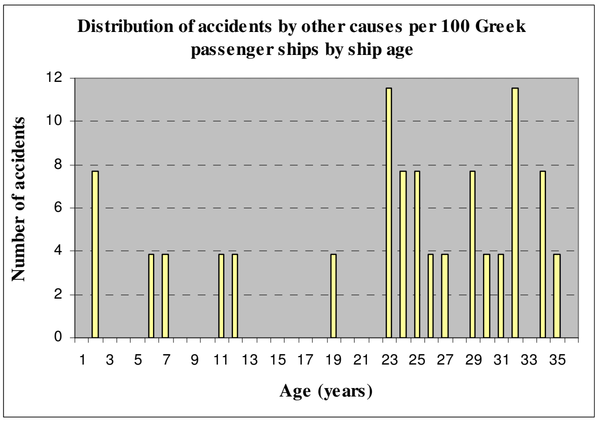


Figure 8: Age distribution of accidents by other causes per 100 Greek passenger ships by ship age illustrated with a histogram, 1992 – 2005

In **Figure 8** it is shown the age distribution of accidents that are attributed to other causes. The observed differences in accident frequencies between these distributions do not seem to be dramatic. In this case, the majority of accidents (77%) related with ships 18-35 years old, too. Moreover, the Student's T-test performed for the different causes (human factor and other causes) did not indicate any statistical difference (t=0.638, p-value=0.525>0.05).

Table 1: Basic parameters of the probability mass functions of passenger ships that suffered an accident from human factor and other causes, 1992 – 2005

	Human Factor	Other Causes
Mean *(years)*	22.52	21.96
Mode *(years)*	23, 27, 28	22, 31
Median *(years)*	25	24
Std. Deviation *(years)*	8.60	9.92
25% percentile *(years)*	19.75	18.5
75% percentile *(years)*	28	28

Comparing the basic parameters (**Table 1**) of the two distributions, the similarities between them are quite obvious. The only thing that it can be noticed is the difference in standard deviation, which reflects that the age distribution of accidents from other causes is more spread than the one from human factor. This can be easily viewed in the error bar chart in **Figure 9**. An error bar chart shows the mean value of a score for different groups. In effect, along with the mean, the plots show an error bar which is shown as a "T" and an upside-down "T" on top of and below the symbol. If another random sample of values of the same distribution (from the same population) is drawn, it is 95% likely that the mean for the new sample will fall in the area bounded by the two error bars ("T" characters).

Hence is it the comparison between the age distribution of passenger ships with marine accidents caused by human factor with the one of accidents from other causes sufficient enough to draw a definite conclusion about the correlation of the age of a ship and the cause of an accident? As already mentioned, it is a good start but more pieces of the puzzle must be assembled.

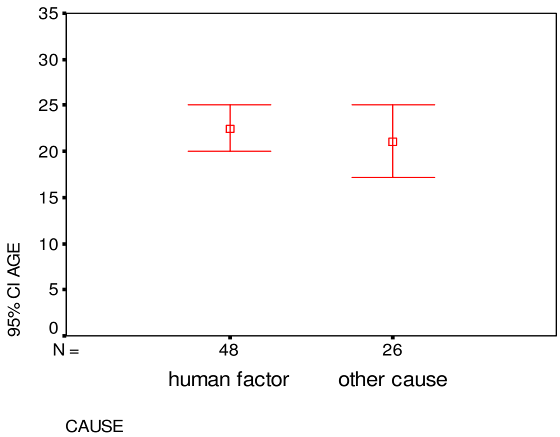


Figure 9: Error bar chart "Age of ship – Cause of accident"

Table 2: Results of Chi-Square test for "Age – Cause"

χ^{2*}	1.51
degrees of freedom	3
p-value	0.1<p<0.5

* $\chi^2_{0.05,3} = 7.82$

** $\alpha = 0.05$

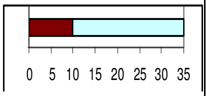
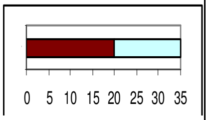
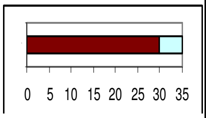
The results of the Chi-Square test are shown in Table 2. The p-value for the data has been estimated between 0.1 and 0.5. Hence one can not positively claim that the probability of having a marine accident from human error or from other causes depends on the ship age, as the p-value gives the print to accept the null hypothesis; that the age of a passenger ship and its cause of the marine accident are independent facts.

Differences among Age Categories

All evidence – until now – lead us to the conclusion that the age of a ship cannot be related to the cause of the accident and, more specific, that would be an outcome of human error or other causes. This section of the paper tries to test the possible differences among the age categories and to identify the ones that seem to have a larger tendency to be involved in a marine accident caused by human factor.

Table 3 presents the values of the odds ratio comparing each time two age categories in relation to their probability to be involved in a marine accident caused by human factor. As it is shown from the results, it is almost equally likely to have a marine accident from human error for a passenger ship up to 10 years old or over 10 years old (OR = 0.97). The same conclusion stands for the respective comparison between the passenger ships up to 20 years old and over 20 years old (OR = 1.12).

Table 3: Odds ratio and 95% confidence interval for accident by human factor based on ship age

		Odds ratio (OR)	95% CI for OR
	Passenger ships aged up to10 years old	0.97	0.29 – 3.24
	Passenger ships aged up to 20 years old	1.12	0.39 – 3.21
	Passenger ships aged up to 30 years old	2.10	0.67 – 6.60

However, the findings change for the comparison between passenger ships up to 30 years old and over 30 years old, that is passenger ships 31 to 35 years old as in the period 1992 – 2005 the age limit was still in force. In this case, the passenger ships up to 30 years old seems to be twice more prone to have an accident by human factor than the ones over 30 years old. So – inconsequentially that the passenger ships with ship age from the 31 – 35 category exhibit low risk (**Figure 6**) – the marine accidents that take place in these ships show less tendency to have as cause the human error. Of course, it has to be noticed that the lower bound of the confidence interval is lower than 1, which means that this tendency should be assessed with extreme caution from a statistical point of view.

6. Results: Size of Ship and Human factor

Passenger ships appear to be one out of three types of ship that exhibit statistical size dependency (the other two are bulk carriers and tweendeckers)). In particular, for the year 1994 worldwide, the accident risk of passenger ships seem to increase with ship size (Psaraftis et al., 1998). In contrast to this, in period 1992 – 2005, the outcome is quite different for the marine accidents of passenger ships in Greece (**Figure 10**). Passenger ships from 2001 to 5000 GRT seem to be more prone to be involved in a marine accident, while the accident frequencies steadily reduce with ship size from the 2001 – 5000 category to 10000+ one. It should be mentioned, however, that the above results could be rather biased against the larger vessels due to the fact that smaller ship accidents may be under-reported (Psaraftis et al., 1998).

As in the previous section, the research starts with the analysis and comparison between the size distributions of passenger ships that had a marine accident caused by human factor or other causes, respectively. The capacity of the ship is a continuous distribution and the values that can take are from 100GT (as our data refer to Greek ships over 100GT) up to, very large vessels (it is noted that the largest passenger vessel that is recorded within the marine accident list is of size 30010GT).

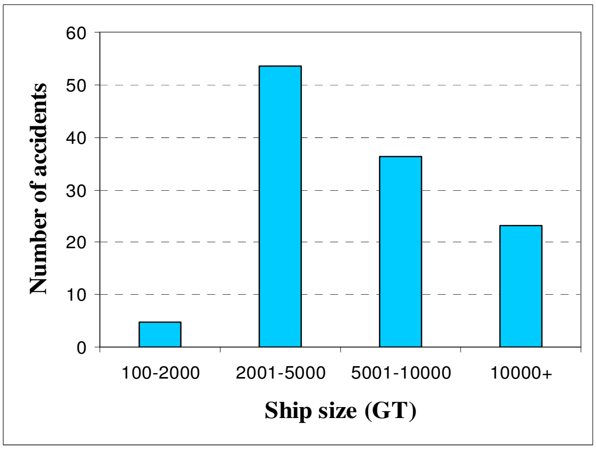


Figure 10: Distribution of accidents per 100 passenger ships by ship size, 1992 – 2005

Examining the empirical probability density function for the passenger ships that had a marine accident caused by the inadequacy of human factor (**Figure 11**), the transposition of the curve towards smaller ships is easily detected. In particular, 81% of all human-driven marine accidents refer to passenger ships up to 5000GT**.**

On the opposite, 54% of the marine accidents caused by other causes points to passenger ships up to 5000GRT; it is noted that Greek passenger ships of this specific size cover the 89% of the whole fleet of Greek passenger vessels (Statistical Service of the Hellenic Ministry of Mercantile Marine) (**Figure 12**). The differences of these two distributions are being revealed clearly, by the comparison of the basic parameters (**Table 4**).

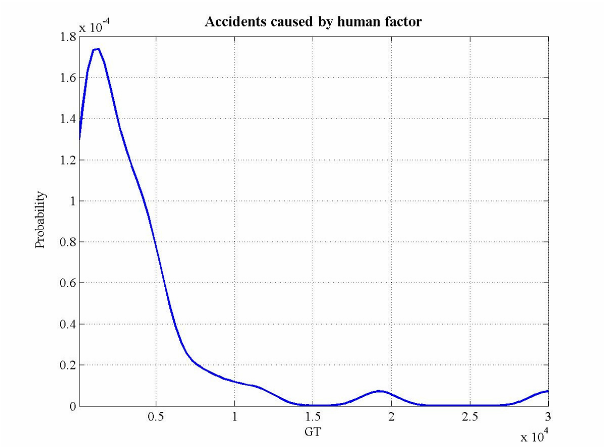


Figure 11: Probability Density Function for the capacity of passenger ships that had a human-driven marine accident, 1992 – 2005

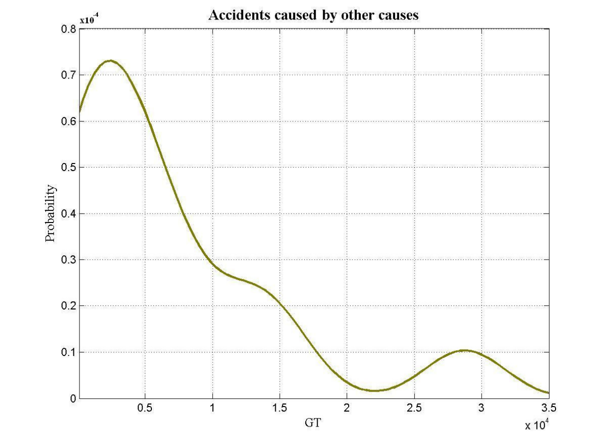


Figure 12: Probability Density Function for the capacity of passenger ships that had a marine accident caused by other causes, 1992 – 2005

Table 4: Basic parameters of the distributions of passenger ships that suffered an accident caused by human factor and other causes , 1992 – 2005

	Marine Accidents from Human Factor	Marine Accidents from Other Causes
Mean *(GT)*	3729.3	6871.2
Median *(GT)*	2271	4052.5
Std. Deviation *(GT)*	5184.1	8004.8
25% percentile *(GT)*	956	555.5
75% percentile *(GT)*	4243.75	10246.75

However, are these differences – like the ones recorded for the mean and median values – statistical significant? The answer will be given from the corresponding statistical tests, that follow hereafter.

On average, passenger ships that had an accident from human error had a capacity of 3729GT, while the ones that had an accident caused by other causes had a capacity of 6871GT. The results of the Student's T-test demonstrate that this difference is statistical significant ($t=-2.045$, $p\text{-value}=0.044 < 0.05$).

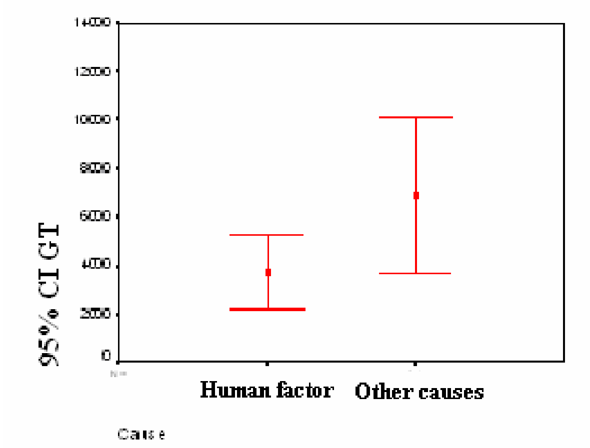


Figure 13: Error bar chart "Size of ship – Cause of accident"

The difference between the means of the two distributions can be manifested with the aid of an error bar chart (**Figure 13**). The upper limit of the 95% confidence interval for the average capacity of passenger ships that had an accident caused by human factor is under the average capacity of passenger ships that have been involved in a marine accident from other causes, confirming the Student's T-test results

In terms of the difference between the medians of the two distributions, the results of the Wilcoxon Signed-Rank test are clear. The extremely low p-value depicts the statistical difference of the two medians.

Table 5: Results of Chi-Square test for "Age – Cause"

χ^{2*}	8.86
degrees of freedom	3
p-value	0,010<P<0,025

* $\chi^2_{0.05,3} = 7.82$

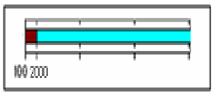
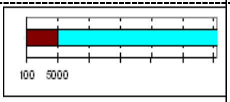
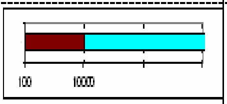
** $\alpha = 0.05$

The same methodology applied for ship ages was employed to investigate possible dependency of the cause of marine accidents in relation to ship size. **Table 5** presents the results of the implemented Chi-Square test. The very low p-value renders almost certain that the size of a vessel influences its probability of being involved in an accident caused by human factor or other causes.

Differences among Size Categories

The research until now shows clearly that the size of a passenger ship can be statistically linked to whether an accident would be the result of a human error or not. More specifically, smaller ships seem to be more prone to be involved in a marine accident by human factor than bigger ones. In particular, passenger ships from 100 up to 5000GRT are 4.33 times more likely to have an accident that can be attributed to human factor than passenger ships over 5000GRT. Also, passenger ships from 100 – 10000GRT are 5.5 times more prone to be involved in marine accident by human factor. As it is shown in **Table 6**, the fact that the lower bounds of the 95% confidence intervals are over 1 makes this tendency statistical significant

Table 6: Odds ratio and 95% confidence interval for accident by human factor based on ship age

		Odds ratio (OR)	95% CI for OR
	Passenger ships up to 2000GRT	2.30	0.85 – 6.21
	Passenger ships up to 5000GRT	4.33	1.54 – 12.20
	Passenger ships up to 10000GRT	5.53	1.33 – 23.02

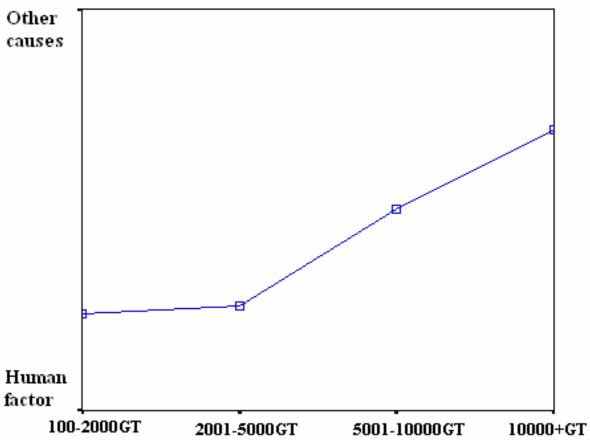


Figure 14: Tendency of size categories to be involved in an accident due to human factor or other causes

For reasons of completeness, **Figure 14** presents the tendency of the four size categories to be involved in a marine accident either due to human factor or due to other causes. Hence, it is evident that the accident risk that is related to the insufficiency of human factor reduces with ship size. Moreover, as it has been mentioned above, the accident frequencies steadily reduce with ship size from the 2001 – 5000GT category to the 10000+GT one. The connection of these very interesting prints points out expressively the adverse role of human factor: as the impact of human factor gets more intense for a specific size category, so the risk for a marine accident gets higher for this category.

Distribution Fitting

The fact, that research indicates a statistical link between the size of Greek passenger ships and the cause of a possible accident, was a good reason to wonder if and to what extend can be fitted the empirical distribution, that came out from the values of the capacities of the passenger ships that had an accident, with one of the well known continuous theoretical distributions.

This action can give the opportunity for a more convenient examination about the link of these two factors. Moreover, in this manner, the re-estimation of the situation in the near future can be attempted more easily.

The theoretical distribution that approximates the empirical one – which came up from the capacity values of passenger ships that had a marine accident caused by human factor – is an exponential distribution. The general formula for the probability density function of the exponential distribution is:

$$f(x) = \frac{e^{-x/\chi}}{\beta} \;,\; \beta > 0$$

, where β is the scale parameter. About exponential distribution also stands:

mean = E(X) = β
variance = Var(X) = β^2
standard deviation = σ = β

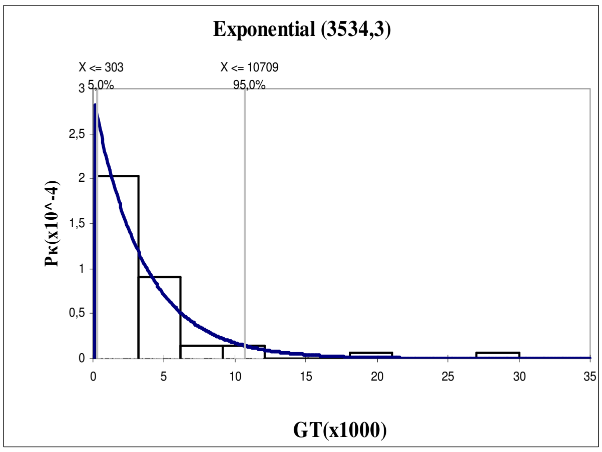


Figure 15: Distribution fitting of the empirical distribution for the size of Greek passenger ships that had an accident caused by human factor with an exponential (theoretical) distribution

For this case, the value of the scale parameter is 3524.3 and the graph of the probability density function can be seen in **Figure 15**. The fit statistic that that was implemented for measuring how good the theoretical distribution fits the empirical one is the chi-square statistic test.

The p-value that was calculated is very high (p-value = 0.885) and, additionally, the test statistic value is lower than the critical value:

test value = $3.00 < \chi^2_{7,0.05} = 14.07$ (2)

Moreover, the same methodology was applied for the empirical distribution for the size of Greek passenger ships that had a marine accident due to other causes. Hence, in this case, too, the exponential distribution approximates the theoretical one (**Figure 16**). The results of the Mann-Whitney U test (p-value > 0.05) confirm this result, as they depict that the null hypothesis – that the distributions of the two populations, from which the samples were taken, are the same – must be accepted. Namely, both empirical distributions can be fitted with an exponential (theoretical) one.

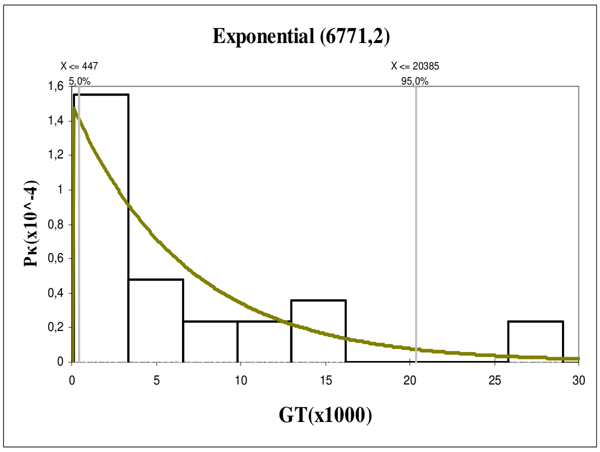


Figure 16: Distribution fitting of the empirical distribution for the size of passenger ships that had an accident due to other causes with an exponential (theoretical) distribution

The scale parameter β for this function is 6771.2GT, almost twice the one of accidents caused by human inadequacy. In effect, the distribution that can cover the size of the passenger ships that had a marine accident from human error is much less spread and has a clear transposition towards smaller ships.

It has to be noticed that the p-value that was calculated in this situation was 0.406 (less than the previous one), but the test statistic value is lower than the critical value:

test value= $4.00 < \chi_{4,0.05} = 9.49$ (3)

, so as the distribution fitting can be deemed as accepted.

7. Conclusion – Discussion

Greek coastal shipping – as the whole maritime field and, in general all modern industries – is transparently affected by human factor. This is not a surprise, however, it is extremely worrying because the confrontation of this imponderable factor is always a predicament. A very important concern is, also, the fact that, during the period 1992 – 2005, it is not marked any remarkable tendency of reduction in the frequency of Greek passenger ships' accidents.

The results of the research regarding possible correlation of the age of Greek passenger ships with the main cause of accidents, hence the human factor, do not reveal any statistical connection. The accident frequency of ships aged 21-25 years old is the higher among all age categories, while an interesting observation is the reduction of the frequency of accidents for the ships of over 25 years old.

Passenger ships of 11-30 years old present the higher tendency for accident caused by human negligence. This tendency is reduced for ships of 1-10 years old, as it is quite reasonable that certain problems appear during the first years of operation of a ship due to error operations at the building.

On the contrary, the size of Greek passenger ships is demonstrated to be connected with the cause of a marine accident. The passenger ships of 2001-5000GT seem to more prone in marine accident than the other size categories, while at the same time for these ships the tendency for accident due to human factor is exceptionally increased. Moreover, the increased tendency of smaller passenger ships to suffer a marine accident caused by human negligence is getting attenuated and, finally, it is reversed with the increase of size of Greek passenger ships.

The effort for the increase of the level of safety of Greek coastal shipping is obligation of all involved institutions and right for every passenger. The further enhancement of safety is a direct consequence of restriction of the main cause of accidents; the human factor. This mission is exceptionally difficult and aims at a lot of parameters, however the prevention of even one accident or of even one human loss, makes it an imperative need.

Fundamental axes to this purpose should be:

i) the complete analysis of human behavior, the comprehension of capabilities, limitations and needs of human being and the attendance of the suitable persons on studying and planning issues.

ii) the safety culture, that should govern all the levels in the chain of command of Greek coastal shipping, constituting an integral part of the work and that will be recognized by everyone as essential for the achievement of the target.

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