AN ANALYSIS OF MARITIME TRANSPORTATION RISK FACTORS

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ABSTRACT

This paper presents an analysis on the factors that are important determinants of maritime transportation risk. The analysis has been part of an international, multi-partner project. The purpose of the project has been to identify technologies and other measures to improve maritime safety, mainly in the context of European waters.

1. INTRODUCTION

The purpose of this paper is to present an analysis on the factors that are important determinants of maritime transportation risk. The analysis has been part of project SAFECO (for "Safety of Shipping in Coastal Waters"), an international, multi-partner project funded by the Commission of the European Communities. The purpose of the project has been to identify technologies and other measures to improve maritime safety, by analyzing the impact of maritime simulators, collision avoidance systems, improved maneuverability, and related technologies[1].

Several organizations conduct analyses, publish regular statistical updates, and maintain databases of maritime casualties. For instance, the Lloyds Maritime Information Services (LMIS) compiles a database and publishes "World Maritime Casualty Statistics", a statistical update of all major maritime casualties in the world. Agencies such as the UK Department of Transport's Maritime Accident Investigation Branch (MAIB) and the Institute of London Underwriters (ILU) issue such updates based on data collected by them. Other than Lloyds Register, classification societies such as Det Norske Veritas conduct their own statistical updates of maritime casualties, which they use mostly for their own internal purposes of for background analyses to support safety related measures. The use of bulk carrier casualty statistics to support the recent guidelines of the International Maritime Organization (IMO) and of the International Association of Classification Societies (IACS) on bulk carrier safety is one (but certainly not the sole) example. Last but not least, we note that some of the above analyses (particularly the ones on damage and insurance claims) are carried out for proprietary reasons and are not available to the public.

Within the SAFECO project, the objective of the so-called "Historic risks and validation model" has been to assess the overall level of risk, identify statistics for verification of the risk, identify important risk reduction factors, and identify cases for assessment of the merits (or lack thereof) of specific risk reduction schemes for marine safety in European coastal waters. To that effect, the National Technical University of Athens (NTUA) spent considerable effort searching for and looking at shipping casualty data worldwide. Two such sources were tapped:

- The first has been the Lloyds List Casualty Reports (a weekly publication). A worldwide database was developed from raw data from this source. This database closely emulates the LMIS database.

- The second source has been the casualty files from the Greek Ministry of Merchant Marine, limited to Greek flag ships (on a worldwide basis). The files go into considerable detail on responsibilities, causes, and other details on each event. Another database on this data was developed.

The analysis reported in this paper is based on data from the *first* database listed above. The second database was used for an analysis of main *causes* of accidents, an analysis which will not be reported here (this analysis is reported in a SAFECO internal technical report, ref. [2]). One of the key questions that are addressed in the analysis of the present paper is whether one can identify *factors* such as ship size, type, age, weather, casualty, geographical location, or others that make *a statistically significant difference* on maritime transportation risk. 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.

Even though many maritime casualty statistics and analyses have been and are being produced by several sources, they

[1] Main partners in the SAFECO project: Det Norske Veritas (consortium leader), Danish Maritime Institute, Port of Rotterdam, National Technical University of Athens, Kongsberg Norcontrol, Kelvin Hughes, Instituto Superior Tecnico, Marine Safety Rotterdam, Riso National Laboratory.

typically only provide a *first order* analysis of what may be important risk factors. To our knowledge, little or nothing in the maritime casualty literature addresses the issue of *statistical significance.* This is in contrast to the literature on *air safety*, in which some work along these lines has been reported. *To the best of our knowledge, ours is the first analysis of maritime casualty statistics that goes beyond a first order approach and draws conclusions related to statistical significance.*

The reader should be aware that due to space limitations this paper necessarily cannot go into all the details of the analysis. These can be found in a SAFECO internal report, ref. [1].

2. DATABASE DESCRIPTION

As mentioned earlier, the weekly "Lloyd's Casualty Reports" were used as the source of information on accident-related data. Although this publication does not specify the accident cause, it reports the sequence of events which took place between the initial problem and the final outcome of the accident. This allows the definition of the *type* of the accident, which constitutes a central piece of information for the present study. In most cases the reports also contain information on the location of the accident, the prevailing weather conditions and the outcome in terms of loss of life or injuries and pollution to the environment. Furthermore, the Lloyd's reports provide global coverage of the entire world fleet, which is important if geographic or flag-specific biases are to be avoided.

The 52 issues of the Lloyd's reports published during 1994 were used for the analysis. Altogether, they contain more than 7,000 accident reports, a number that was in retrospect proved sufficient for the statistical analysis, since its results proved to be quite similar to the results of another analysis carried out later independently by DNV and arriving roughly at the same conclusions (ref. [3]).

The necessary information regarding the size and composition of the world fleet, as well as a number of specific characteristics (ship type, size and age, flag, country of ownership and classification society) of the vessels involved in the accidents were obtained from the database of Fairplay Information Systems.

As designed initially, the database contained 38 fields. The fields, the codes used and the relevant groups that were formed for the subsequent statistical analysis are presented below (see [1] for details in the definitions of these variables):

1. *SHIP NAME.*

2. *SHIP TYPE.*

3. *YEAR BUILT.*

4. *GROSS REGISTERED TONNAGE (GRT).* The analysis was restricted to vessels over 1,000 GRT.

5. *CARGO TYPE.*

6. *FLAG.* The flag groupings which were formed for the purposes of this analysis are presented below:

   - EU (EU countries, Norway and corresponding second registers)
   - OECD (OECD countries not belonging in other groups)
   - CONV (flags of convenience)
   - SAME (South America)
   - SEAS (South - East Asia)
   - FSU (Former Soviet Union and Eastern Block Countries)
   - OTH (other countries)

7. *COUNTRY OF OWNERSHIP.*

8. *NUMBER OF OWNERS* during the vessel's life.

9. *LAST MANAGER.*

10. *CLASSIFICATION SOCIETY.*

11. *LR NUMBER.*

12. *DEPARTURE PORT.*

13. *DESTINATION PORT.*

14. *ACCIDENT 1,* as it appears in the "Lloyd's Casualty Reports". Each marine accident can be described by a series of distinct events that take place in a specific order. For example, it is possible that a ship experiences main engine problems, which under certain circumstances can cause drifting, grounding and eventual sinking. Since both the types of events that constitute an accident and the particular order in which they happen are very important elements for the analysis, the database contains 5 separate fields for that purpose. It follows that each accident can be described with up to 5 distinct events. ACCIDENT 1 refers to the first such event in chronological order. The accidents are grouped into the following groupings:

    - Foundering
    - Missing
    - Fire / explosion
    - Contact / collision
    - Grounding
    - War Loss / hostilities
    - Mechanical problem

- Hull problem
- Navigational problem
- Other problem (not specified above)

15. *DATE 1,* as specified in the "Lloyd's Casualty Reports". It refers to the date that ACCIDENT 1 occurred.

16. *ACCIDENT 2,* as it appears in the "Lloyd's Casualty Reports". It refers to the second in the series of events constituting a single accident (in chronological order). The codes and categories are identical to those of ACCIDENT 1.

17. *DATE 2,* as specified in the "Lloyd's Casualty Reports". It refers to the date that ACCIDENT 2 occurred.

18. *ACCIDENT 3,* as it appears in the "Lloyd's Casualty Reports". It refers to the third in the series of events constituting a single accident (in chronological order). The codes and categories are identical to those of ACCIDENT 1.

19. *DATE 3,* as specified in the "Lloyd's Casualty Reports". It refers to the date that ACCIDENT 3 occurred.

20. *ACCIDENT 4,* as it appears in the "Lloyd's Casualty Reports". It refers to the fourth in the series of events constituting a single accident (in chronological order). The codes and categories are identical to those of ACCIDENT 1.

21. *DATE 4,* as specified in the "Lloyd's Casualty Reports". It refers to the date that ACCIDENT 4 occurred.

22. *ACCIDENT 5,* as it appears in the "Lloyd's Casualty Reports". It refers to the fifth in the series of events constituting a single accident (in chronological order). The codes and categories are identical to those of ACCIDENT 1.

23. *DATE 5,* as specified in the "Lloyd's Casualty Reports". It refers to the date that ACCIDENT 5 occurred.

24. *CAUSE OF ACCIDENT,* as identified in the "Lloyd's Casualty Reports". There are no codes or categories, as the variable is of rather descriptive nature.

25. *RESULT OF ACCIDENT*, as specified in the "Lloyd's Casualty Reports". Provided that the most significant accident results in terms of lives lost, injuries and environmental pollution are specified in other fields of the database, the scope of this field is basically limited to damages to the vessel and her cargo. There are no codes or categories for this variable.

26. *RESPONSIBILITY,* as indicated in the "Lloyd's Casualty Reports". Again, due to the descriptive nature of the variable, there are no codes or categories.

27. *GEOGRAPHICAL LOCATION,* as specified in the "Lloyd's Casualty Reports".

28. *GEOGRAPHICAL CODE 1,* depending on the broad geographical area (circled numbers), containing the location of the accident.

29. *GEOGRAPHICAL CODE 2,* depending on the particular cell in the grid that contains the location of the accident.

30. *LONGITUDE* of the accident location, as specified in the "Lloyd's Casualty Reports".

31. *LATITUDE* of the accident location, as specified in the "Lloyd's Casualty Reports".

32. *ENVIRONMENTAL CATEGORY,* as specified in the "Lloyd's Casualty Reports". The codes used are:

1	Non-tidal waters	4	Coastal waters
2	River / canal	5	High seas
3	Port / harbor area		

33. *LIVES LOST,* as specified in the "Lloyd's Casualty Reports".

34. *INJURED,* as specified in the "Lloyd's Casualty Reports".

35. *POLLUTION,* as indicated in the "Lloyd's Casualty Reports". The codes used are YES / NO

36. *WEATHER,* as specified in the "Lloyd's Casualty Reports". The following codes were used:

1 Calm seas (good weather)
2 Storm (heavy weather, bad weather, heavy seas, rough seas, squall, heavy swell)
3 Snowstorm (snow, freezing conditions)
4 Typhoon (hurricane, cyclone, tornado, freak weather conditions, freak seas).

37. *VISIBILITY,* as specified in the "Lloyd's Casualty Reports". The codes used are GOOD / BAD

38. *TEXT.* This is a free text field for comments of any sort.

The number of records contained in all 52 issues of the "Lloyd's Casualty Reports" published in 1994 is 7,553. All these records were entered in the database.

The data screening was performed in 6 stages. Firstly, 917 vessels of GRT below 1,000 tons were deleted from the database, reducing the number of records to 6,636. The second stage concerned the type of the ships. The miscellaneous and offshore vessels, 1,013 in total, were excluded from the database, bringing its records down to 5,623. At the third stage, 2,079 ships were deleted as there was no accident specified (no entry in the ACCIDENT 1 field), reducing the number of records to 3,544. A further 411 records were excluded from the database in the fourth stage, as the relevant accidents did not occur during 1994, but in earlier years. From the remaining 3,133 records, 180 were deleted as double entries, due to the fact that the same accident was reported in two or more issues of the source publication. Finally, 904 records were excluded because the accident type "seizure" (code 824) was specified in field ACCIDENT 1, meaning that the corresponding vessels were seized/arrested for reasons other than technical deficiencies. In the latter cases, seizure appears as following other accident types. A final number of 2,049 records resulted from the screening described above.

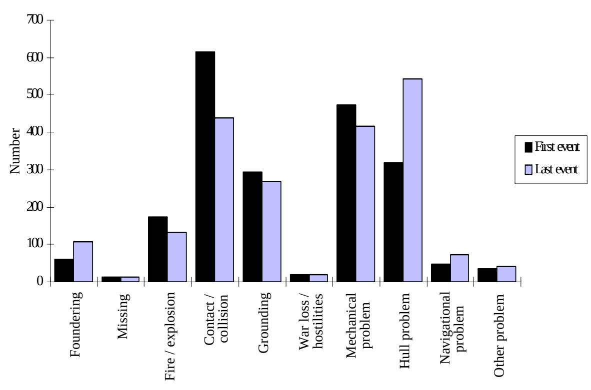
3. STATISTICAL ANALYSIS

3.1 The first and last events as factors of marine accidents

As mentioned in Section 2, an accident is described in the database by a series of up to five distinct events that take place in a specific order. We start our analysis with the first and last of such events. The former is important due to its proximity to, and hence its correlation to the cause of the accident, while the latter basically describes the result of the accident.

As shown in Figure 3.1, the most common type of first event is contact/collision (30.1% of the total), followed by mechanical problems (23.0%), hull problems (15.5%) and groundings (14.2%). The same four types occupy the top of the list of last events, but now the order is different. Most accidents end up with hull problems (26.5%), followed by contact/collision (21.3%), mechanical problems (20.4%) and groundings (13.0%).

Figure 3.1: Distribution of the first and last events by type of accident



3.2 Ship type as a factor of marine accidents

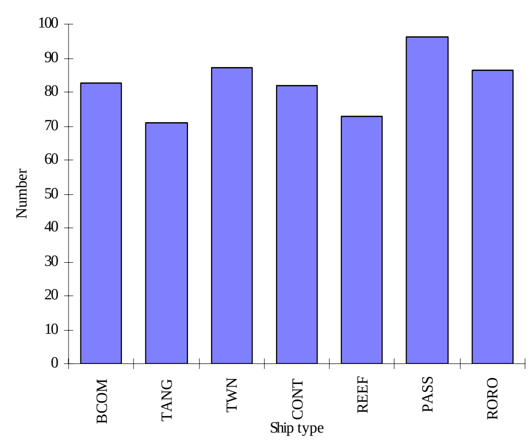
In order to investigate whether the probability of having an accident is influenced by ship type, data on the composition of the world fleet was required. A statistical test had to be employed to check whether statistically significant dependence between the variables "accident/no accident" and the ship type exists.

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. 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.

The p-value for the data has been estimated at 0.009. It follows *that one can positively argue that the probability of having a marine accident depends on the ship type, as some types are more prone to accidents than others.* It appears from Figure 3.2 below that passenger vessels are characterized by the highest likelihood of having an accident (96 ships in a thousand) followed by tweendeckers (87/1000) and ro-ro vessels (86/1000). It is no coincidence that due to their nature all these vessels call at ports much more often than the ships of the other types. Tankers exhibit the lowest probability of being involved in an accident (71/1000).

It should be mentioned, however, that the differences in frequency figures among ship types are not dramatic. One should, therefore, try to confirm the observations made above by analyzing data of other years.

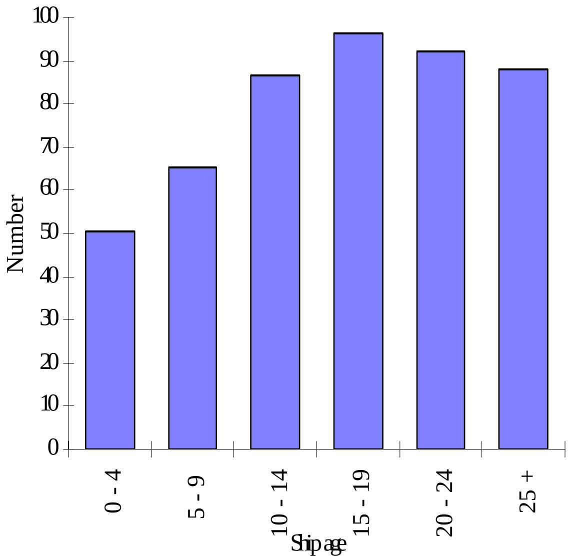
Figure 3.2: Distribution of accidents per 1000 ships by ship type



3.3 Ship age as a factor of marine accidents

The same methodology applied for ship types was employed to investigate possible dependency of marine accidents to ship age. Figure 3.3 presents the results of the analysis. The very low p-value renders almost certain that the age of a vessel influences her probability of being involved in an accident. As expected, the accident frequencies steadily grow with ship age from the 0-4 category to the 15-19 one, which exhibits the highest risk. It is interesting to note that beyond the limit of 19 years of age, the risk of getting involved in an accident, although remains in relatively high levels, it is slightly reduced with the age. A possible 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 she reaches her 19th year of age. In the same spirit, there are good chances that, for financial reasons, problematic vessels would have to be scrapped when time is up for the fourth survey. The excessive use of high tensile steel for vessel construction during the early eighties can also be a factor contributing to the risk peaking at the 15-19 group (96/1000).

Figure 3.3: Distribution of accidents per 1000 ships by ship age



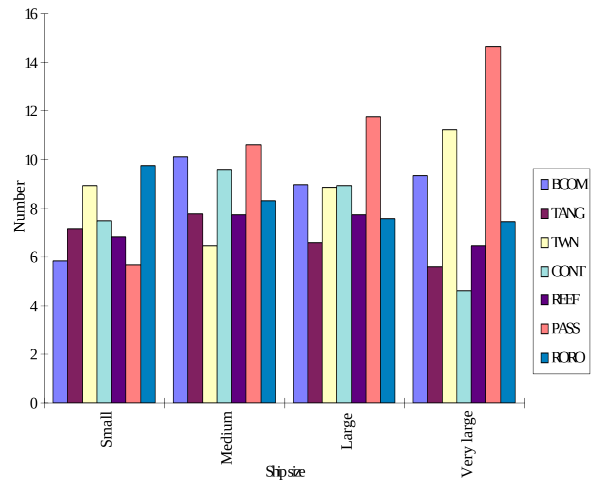
3.4 Ship size as a factor of marine accidents

The results of the investigation of possible dependency of marine accidents to the size of the vessels are presented in Figure 3.4. It appears that among the seven types of ships examined, only three exhibit statistically significant size dependency: the bulk carriers, tweendeckers and passenger vessels. Bulk carriers in the 8,000-19,999 GRT range show the highest risk (10%), while the smaller vessels are the safest (6%). A possible explanation could be the fact that the ships of the 8,000-19,999 GRT category are among the largest vessels of this type carrying their own cargo handling equipment.

In general, the accident risk of tweendeckers follows an upward sloping curve with the size of the vessels, which can be attributed to the increased difficulty of ship maneuvering inside harbor areas, which is inherent to the larger vessels. The rather high risk exhibited by the smaller vessels can be viewed as an exception due to the higher frequency of port calls that characterizes these ships. A profound upwardly moving curve is followed by the accident risk of passenger vessels, most probably due to the same reasons.

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.

Figure 3.4: Distribution of accidents per 100 ships by ship type and size



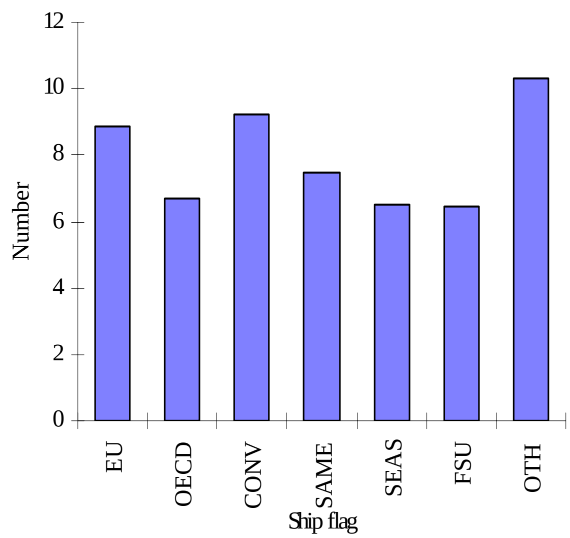
3.5 Ship flag as a factor of marine accidents

One can certainly not claim that "flag", in and of itself, is one of the possible causes of a marine accident. However, we think that an analysis of flag as a factor of risk is important because flag may be considered as a "proxy" for other variables that cannot be easily measured, such as crew training, crew composition, and others. This section tries to shed some light on this issue, however we must state that its results should be interpreted with caution.

According to the results of the analysis (see also Figure 3.5), the dependency of accident risk on the flag of the vessel is beyond any doubt, as this hypothesis is statistically significant at the 99.9% level. The group OTH, which consists of a great number of developing countries around the world, exhibits the highest risk (10/100). The second most risky category is the group of flags of convenience at 9/100, a very important fact due to the volume of the world fleet flying these flags (36.8% of the fleet in terms of number of ships).

Surprisingly enough, the EU flags exhibit comparable risk levels to those of the group of flags of convenience (slightly less than 9/100). Given the significance of the EU fleet (19.0% of the world fleet), this is also a very important fact. The fleets of South American, other OECD and Southeast Asian countries, as well as those of the former Eastern Block countries form the below average risk bracket. It should be mentioned that this might be due to under-reporting of marine accidents in these countries. However, the degree of such under-reporting, if in fact it exists, is not known.

Figure 3.5: Distribution of accidents per 100 ships by flag



In order to investigate the matter in more detail, the chi-square test was applied to the group of flags forming the EU category (EU member states, Norway and related second registers). The results show that ship flag remains a statistically significant factor of marine accidents.

Belgium occupies the top of the list in terms of risk (28/100), but this is of minor importance due to the limited fleet of this country. The second most risky and at the same time significant maritime nation seems to be Great Britain at 14/100, followed by Luxembourg (107/1000). Greece (22.1% of the EU fleet in terms of number of ships) and Germany (11.4% of the EU fleet) share the fourth position at 105/1000, followed closely by France and Eire (102/1000). The significant registers of DIS (Denmark's international register), NIS (Norway's international register), Norway, Denmark, Spain, Netherlands, Sweden and Italy appear in the low risk region at descending order of risk. The lowest risk is exhibited by Portugal at below 3/100, which however, is of limited importance due to its small fleet.

It is important to mention at this point that the results depend to a large extent on the quality of the data that was analyzed. It is expected that the accident reporting systems of the various flag states differ from each other. This lack of homogeneity in data quality seems to penalize flags that have in place good accident reporting systems (the UK being the prime example). Thus, it is suspected that 'distance from London' is indeed a factor affecting the perceived risk of accidents.

A separate investigation was performed regarding the second registers of DIS, NIS and IOM (Isle of Man). The observed differences in accident frequencies, however, between these registers and those of the associated country registers proved statistically insignificant and the matter was not pursued any further.

A detailed analysis of the OECD flag group was also performed, confirming the significance of ship flag in marine accidents. Canada, Australia, Switzerland and Turkey are the riskiest fleets with frequencies ranging from 157 to 109 per 1000 ships. At the other end, Iceland and Japan exhibit the surprisingly low risk levels of 17/1000 and 25/1000 respectively.

We also examined the dependency of each type of accident occurring as first or last event on the flag of the ship. Regarding first events, it seems that contacts/collisions, groundings, and mechanical and hull problems are influenced by the flag. The OTH flag group exhibits the highest risk for all types of accident except contacts/collisions and groundings, for which the Southeast Asian and the EU/South-American flags are the most accident prone respectively. The last event analysis leads to identical results. It is worth mentioning that navigational problems have now joined the group of the flag dependent accidents.

An effort was also made to investigate the existence of possible dependency between ship type and flag. It appears that flag does influence the accident frequencies of bulk carriers, tweendeckers and passenger vessels. It might be for commercial or historical reasons that certain flags tend to attract some types of vessels more than others do.

3.6 Country of ownership as a factor of marine accidents

It is clear that the country of ownership of a ship is not always an unambiguous variable, particularly if it is difficult to trace who is the real owner of the ship. However, an analysis of this variable is again important, for the same reasons as those analyzed earlier, that is, that this variable may be considered a "proxy" variable for other variables that cannot be easily measured. For the purposes of this analysis, we have taken "ownership" as listed in the Fairplay database, with no attempt to get deeper on who is the real owner. Therefore we state again that the results of this section should be interpreted with caution.

Country of ownership proved to be another statistically significant factor affecting marine accident frequencies. EU appears to be the most risky ownership group exhibiting a frequency of 7/100. The OTH group, which now contains also the countries of flags of convenience, follows closely at 67/1000. The South American, Southeast Asian, OECD and former Eastern Block groups of ownership lie all on the below average risk side. The comment on possible under-reporting of marine accidents in these countries, made in the context of ship flags, may also apply here.

The results of a more detailed analysis on EU ownership are presented showed that Eire is the country which exhibits the highest level of risk at 102/1000. Great Britain, Greece and Germany, controlling between them 54% of the EU fleet, remain at the top of the risk ladder with frequencies ranging from 90 to 72 per thousand. As was the case with ship flags, Italy and Portugal own the safest fleets (the zero frequency of Luxembourg cannot be compared to those of the other nationalities due to the negligible size of this country's fleet). The 'distance from London' factor mentioned in the previous section, should be taken into consideration in qualifying these results as well.

The corresponding results for the OECD group of ownership simply confirm the findings of the previous section concerning the flag of the vessels.

An additional investigation was carried out at this point in order to check whether the fact that a ship's flag does not coincide with the country of her ownership could have an effect on the risk level. The analysis covered the entire fleet, as well as each flag group separately. In no case a statistically significant dependency was identified.

An analysis concerning the existence of possible dependency between the type of accident appearing as first or last event and the country of ownership revealed some interesting patterns. Regarding first events, it appears that founderings, fires/explosions, contacts/collisions, groundings, and mechanical and hull problems are influenced by the country of ownership. Before reaching solid conclusions, the possibility of dependency between ship type and country of ownership was investigated. One can argue that what appears as dependency of fires/explosions and mechanical problems to the country of ownership can be attributed to the type of ships which are prone to these types of accident and the relative concentration of these ships to specific countries of ownership.

3.7 Classification society as a factor of marine accidents

The classification society of a ship seems to be yet another indirect factor affecting the level of risk. Our analysis showed that LR shows the highest accident frequency (69/1000), followed by GL (66/1000), EUR (63/1000), AB (61/1000) and DNV (59/1000). Significantly lower frequencies are exhibited by OTH (49/1000), JAP (36/1000) and FSU (34/1000). It should be mentioned again that the lack of homogeneity in data quality could penalize classification societies associated to good accident reporting systems.

The existence of possible dependency of the type of accident on the ship's classification society was examined next. For both first and last events, fires/explosions, contacts/collisions, and mechanical and hull problems are indeed influenced by the ship's classification society. *However, these results, looking into the dependency of ship type and classification society, combined with those presented in previous sections, lead to the conclusion that the observed dependencies between fires/explosions, and mechanical and hull problems can be attributed to the type of ships that are usually involved in these accidents and the fact that certain types of ships tend to be classified by some societies more often than the others.* Similar arguments cannot explain the dependency of contacts/collisions on classification.

4. DISCUSSION

Several other analyses that do not appear in this paper due to space limitations were carried out. These include higher order analyses in which possible correlations between pairs of variables are analysed, rather than examining these variables in isolation. For more details, see ref. [1].

In spite of the many difficulties associated with obtaining data of acceptable quality to perform the analysis, we believe that its results are interesting and significant.

We first acknowledge one obvious limitation of the analysis. Clearly, stronger conclusions could be drawn if data covering more years were available. As the analysis covers only 1994 accidents, it can only be considered as a "snapshot", and cannot, in and of itself, identify historical trends in maritime safety. However, historical analyses from other sources show that if such trends exist, they manifest themselves very slowly. This means that they can be identified only if many years of data are available. For various reasons, this proved impossible for this project. Also, we believe that the number of incidents in 1994 is large enough so that an analysis for this year alone makes some sense. A later analysis performed independently by DNV on data from the LMIS database, which covered more years, led to similar conclusions, and hence supports the validity of the results reported here (see ref. [3]).

Another limitation concerns the lack of homogeneity in the quality of the data. This is a direct consequence of both the non-homogeneous quality of reporting of marine incidents *and* of the many deficiencies and ambiguities in the system that is used to encode such events. To be compatible with current practice, we used an encoding system that closely emulates the LMIS system. The lack of homogeneity in data quality seems to adversely penalize countries, flags, and classification societies that are blessed with good accident reporting systems (the UK and Lloyds Register being the prime example). Thus, it is suspected that "distance from London" is definitely a factor affecting the perceived risk of accidents, although it is by no means clear in what fashion.

The most serious deficiency of systems such as LMIS is that information on incident *causes* is almost invariably lacking. For instance, in a collision (which is recorded as two entries in the database, one for each of the two ships involved), the database usually records "collision" as the first event, and then possibly a sequence of subsequent events, such as "fire", "pollution", etc. But the *cause* of the collision (which might be anything like "low visibility", "human error", "fault of the VTMIS system", or any combination of these or other factors) is almost invariably *not* included in the database. This means that any analysis of such database cannot go deep enough on the real causes of the incidents.

The lack of such information is perhaps not surprising. The real cause of an incident is usually not immediately determined, and in fact it may be determined after a long process of investigation. Some accidents may actually remain unresolved for quite a long time, or theoretically forever (the losses of the “Derbyshire” bulk carrier and of the “Estonia” ro/ro ferry are good examples, and the crash of TWA 800 is an interesting parallel in aviation). This means that one needs a different approach if one wishes to consider the causes. Reference [2] reports on such an approach. The main conclusion from the analysis is that most of the accidents have the human factor as the prevalent cause.

ACKNOWLEDGMENTS

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