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ACCIDENT ANALYSIS OF RO-RO SHIPS IN THE GREEK SEA SHORE SHIPPING USING DATA-MINING TECHNIQUES

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Abstract. The paper attempts an accident analysis of Ro-Ro Ships in the Greek Seas for the last 20 years. It attempts to identify some long-established problems of the safety of navigation in Greek waters and specify the principle causes of such incidents. Then, by using data mining methods the paper proposes certain qualitative measures assessing how those accidents should be prevented. The data were assembled from the Ministry of Merchant Marine and include Ro-Ro ships over 100 G.R.T., though the detailed list has suffered a number of omissions.

1. INTRODUCTION

The special characteristic of Greek seas is the presence of scattered islands, islets and rocks that place a heavy burden on long and short-sea shipping. The current problems encountered in those sea areas affecting the safety of navigation are,

- the ever-increasing traffic consisting of bulk carriers, container ships, tankers and other ships passing through destined, either for the Black Sea or the Suez Canal or various ports of the bordering states,
- the increased size and higher service speeds of the conventional passenger vessels operating in coastal trades which lead to problems of insufficient maneuverability in confined waters and considerable loss of turn around time into ports,
- the congestion problems caused by the modern speed-type dynamically supported passenger craft (i.e. catamaran vessels, flying dolphins) and ferries which often turn to quick course changes and short passing distances,
- the uncontrolled increasing traffic during summer periods of large cruisers, pleasure yachts, fishing and sailing boats, fast patrol boats and
- the non-efficiency of the lighthouse and navigating lights network of the coastline and islands which often led in the past to ship accidents or casualties.

Marine accidents are the cause of human error reaching almost 85%. Collisions are always the result of the human factor intervening, particularly focusing in the last decade where a gradual increase in collision incidents may be justified by faulty bridge watchkeeping procedures. Grounding is the result of many factors occurring but again the human element has a vital role. Marine accidents in the passenger and Ro-Ro markets are enjoying a wide media coverage for quite often human losses are involved. This study attempts to approach the initial causes of those accidents presenting parameters such as the specific geographical region, the sea area of the incident, the age of the vessel, the prevailing weather conditions, the types of accidents and the human losses and injuries. The detailed list refers only to passenger ships and Ro-Ro ferries, excluding large cruisers, pleasure crafts, high-speed crafts and ships specifically carrying vehicles.

2. INTERNATIONAL LEGAL FRAMEWORK

It is officially stated within IMO that any serious attempt to improve maritime safety and prevent marine pollution must concentrate on the elimination of human error, because accidents do not happen – they are caused, most of them by people. 'Marine Casualty' is an event that may result in the death of, or serious injury to, a person that is caused by, or in connection with, the operations of a ship; the loss of a person from a ship that is caused by or in connection with, the operations of a ship; the loss, presumed loss or abandonment of a ship, or the involvement of a ship in a collision; material damage being caused by or in connection with the operation of a ship;

damage to the environment brought about by the damage of a ship or ships being caused by or in connection with the operation of a ship or ships.

The first international effort regarding safety regulations for passenger ships appeared in the 19^{th} century deriving from the need to make transatlantic voyages carrying huge numbers of emigrants to the new world (Boison, 1999). The loss of the *Titanic* led to the introduction of new safety regulations (SOLAS 1914). Current regulations on the safety of passenger ships are contained in the SOLAS 1974 version and apply to all passenger ships of any tonnage engaged in international voyages. Other recent serious accidents within the period 1987-1994 led to a substantial reform of SOLAS regulations. On account of those accidents, passenger Ro-Ro ships have been heavily criticized for their lack of subdivision and poor stability. As a result SOLAS was amended several times in order to take emergency steps to make those ships safer. In response to newer ship accidents, the Council adopted several resolutions for improving the safety of Ro-Ro passenger ferries. In addition, all new and existing passenger ships are now divided into 4 classes, A, B, C and D and should adopt certain provisions regarding intact stability, subdivision and damage stability, machinery, electrical installations, additional requirements for periodically unattended machinery spaces, fire safety measures (protection, detection, extinction) and life saving appliances.

3. STATISTICAL DATA ANALYSIS

Specific parameters listed below were used to analyze the accidents' database concerning Ro-Ro Ships sailing in the Greek Seas.

<u>Age of Vessel</u> is a parameter that proved more useful to include instead of the dates referring to the year of built of the vessel and the time that the incident took place. Additionally, another time-factor was decided to be included, the specific 'month' when the incident had occurred, in order to distinguish between winter and summer periods since the Greek Ro-Ro market is of seasonal character.

<u>Geographical Region</u> is based partly on the Greek Hydrographic Survey volumes dividing the Greek Seas into four main regions according to guides for the safety of navigation and partly on the special characteristics of the Greek shipping market. Attribute values include Ionian Sea, Argo-Saronic Gulf, Cyclades, North-West Aegean, North-East Aegean, South-East Aegean, South-West Aegean, Corinthian Gulf, Evoikos Gulf and Cretan Sea.

<u>Weather Conditions</u> is depended on the Beaufort Scale. In particular, 3-4 stands for calm seas, 5-6 means moderate weather, 7 represents rough seas, 8-9 adheres to strong gales and the value of "10" adheres to stormy conditions.

<u>Area of the Accident</u> factor represents five sub-categories. Under the term 'port', we have included incidents such as "port approaches", or "at the entrance of port limits", or "within port area". Under the term 'close to coast' fall certain accidents because in most cases the distance between two island-ports is very short. Under the term 'en route' we usually refer to cases where vessels cover long distances, and finally under the terms 'shipyard' or 'laid up' we have included vessels that were under repairs or have become idle at the time of the accident. The true causes of the accidents have been divided into four main categories. The first refers to the factor.

Initial Cause is equally important because ships do not normally hit the rocks but they are rather steered there. It consists of cases such as 'human error', 'force majeure' including terrorist or fraud acts, 'machinery failure', 'equipment failure' and 'weather conditions'. Somehow, a number of accidents was caused by the combination of two or more initial causes, including incidents such as unexplained occurrences, overloaded conditions, causes other than the vessel herself and random incidents which do not exceed one case per incident. Result of the Accident includes collision, contact, grounding, sinking, fire, and explosion. Note, that in most similar research studies 'fire and explosion' are listed as one accident but in this study we found no case where the first led to the second. Consequently, they were listed as different types of accident.
Other Result of the accident represents the immediate or natural condition following the first result and it was created due to the terminology used by the corresponding applicable law. It includes the terms vessel not under command, flooding, abandoned, partly sinking which in all cases resulted in refloating the vessel and total loss of the vessel.
Damages to Vessel is a factor divided into five sub-categories and includes hull damage, machinery damage, damages to equipment on board, none which clarifies that the vessel suffered no damage and other. The last one includes cases such as damage to other vessels and loss or damage to vehicles on board.
Human Losses , presents figures related to crew or passenger deaths and human injuries.

Finally, under the term **'N/A'** (not applicable) we have included all data that could not be collected or were found insufficient.
Initially we analyzed the complete database by using descriptive statistics methods and results were drawn such as:

- The relation between the number of incidents and the ships' age was expected, because it follows the age distribution of the national fleet. Besides, the majority of the national coastal fleet age-ratio ranges between 26 and 35 years, let alone that 9% of the total, representing those ships that are not involved in regular itineraries, is above 35 years.
- In respect of the geographical region, we have noticed that there is a serious proportion of accidents in the sea areas of Cyclades and Argo-Saronic Gulf. The reason for that is the structure of the coastal network, calling at various ports. Though, in the Argo-Saronic Gulf characterized as sheltered waters, it is surprising to have a high percentage of accidents whereas in the Cretan Sea despite the volume of traffic, a low number of casualties had appeared. The reason possibly is the old age of the vessels involved in Argo-Saronic Gulf itineraries and the presence of scattered islands posing hindrances.
- Almost 60% of the classified accidents have occurred within the port limits and 20% close to the coastline. There are some serious inadequacies involved in port infrastructure and facilities, but this finding must be related with the big number of port calls in accordance to the structure of the coastal network and the number of the islands.
- Human error is the most important initial cause of the accidents, reaching almost 25%, followed by weather conditions reaching 16%, though a substantial number of accidents lacked relevant information and another small percentage could not be identified, being a combination of human error and weather conditions.

- The primary result of the type of accidents proved to be grounding usually in shallow waters within port limits. On the contrary, in E.U. waters the biggest contribution stemmed from fires and explosions where 42 passenger ships were totally lost (Giziakis, 1995). It was followed by the term 'none' meaning that the minor incident did not lead to an accident or casualty. Then fire appears to be another type of accident that did not lead to explosions on board. Finally, contact represented a high percentage and it usually happened when a vessel came in contact with a rock or an islet owing to the poor lighthouse network or bad navigation

4. DATA MINING METHODS

The aim was to use advanced data analysis methods by introducing entropy information based inductive decision trees, resulting from past real world data. Inductive decision trees methodology measures the amount of systematic information contained in all the different aspects of the collected data. The most informative (systematically appearing) characteristic for diagnosis becomes the root of the decision tree and the same process is repeating iteratively for every subset of data resulting from the previous discrimination. A decision tree is formed which is translated by special techniques into a rule- set. Each rule is composed by specific attribute value conditions connected through the logical operator AND, and results to a final decision/classification. The strongest is the rule that "covers" the most cases. Each rule is accompanied by a probability, which corresponds to the successful classification of new cases in the future with respect to this rule. The rule set serves as a unified forecasting/classification model for future events and contains a user-friendly environment for entering any new cases and receiving corresponding decision or forecast (Quinlan, 1993). It is also possible of detecting any misclassifications due to mistakes in the initial data entry. The system accepts both numerical and qualitative variables, while it can manage also missing or unknown values. Finally, it is possible to continuously feed our system with new cases thus adapting our classifier to the current conditions.
Analysis of the specific accident resulted in a quite manageable decision tree, which consists of 50 decision rules in total. Accuracy of the tree as a classifier of the training data used to form it was 100%, i.e. the output performs as a perfect classifier. When the corresponding rules are used to classify the data, two misclassifications are observed, i.e. 2.4% of faulty classification. Here is an example of one of the 50 rules acquired from the application of data mining tool to our accident database:

```
Rule 28: (cover 10)
        Age_of_ship_d-a > 17
        Geographical_Region = CYCLADES
        Area = PORT
    ->  class WEATHER_CONDITIONS  [0.667]
```

This is rule Nr 28, that covers 10 cases, in other words 10 Ro-Ro Ships' accidents, or almost 12% of the total number of accidents happened in the Greek Seas during the last 20 years. The rule claims that when the age of a ship exceeds 17 years, and the

accident has happened near a port of the Cyclades area (i.e. in that part of the Aegean that is full of small pieces of land), then, the accident is more likely to be due to bad weather conditions. It is at least rational and makes sense to relate aged ships and an area full of small islands, to accidents that occur due to weather conditions in front of an approaching port. The rule also informs us that the probability of correctly classifying similar new cases in the future using these specific conditions, is about 66.7 %. The analysis presented here –although indicative in respect to size- is at least interesting for accident analysts in performing decision making in shipping:
Imagine of some large database consisting of thousands of cases of accidents and also containing thousands of attributes and information describing these attributes. What other form of analysis -apart maybe from human expertise- would be able to successfully uncover such hidden complex relations among completely different factors?
Below the accuracy of the system is presented, demonstrating where the misclassifications have occurred, and what the overall accuracy of the classifier is.

```
        Evaluation on training data (83 cases):

          Decision Tree              Rules
        ----------------      ----------------
        Size       Errors       No      Errors

          82     0( 0.0%)       50    2( 2.4%)    <<

        (a)   (b)   (c)   (d)   (e)   (f)  <-classified as
        ----  ----  ----  ----  ----  ----
           8     1                              (a):class
EQUIPMENT_FAILURE
                26                              (b):class
HUMAN_ERROR
                    16                          (c):class
WEATHER_COND.
                          10                    (d):class
MACHINERY_FAIL.
                     1          18              (e):class OTHER
                                      3          (f):class
FORCE_MAJEUR
```

The reader may observe that one accident is due to human error, but the system has misclassified it as equipment failure. Similarly, one case was not recognized as an accident due to weather conditions, but was misclassified as belonging to the general category "other".
The table above contains also information about the number of nodes of the produced decision tree, as well as about the total number of decision rules that correspond to that tree.
Remind that the data-mining method (See5) was applied on 83 out of 104 accidents due to lack of available data in 21 cases. 70 out of 104 accidents had occurred during summer periods (April – October) and incidentally the same ratio appeared when dealing with specific geographical regions. In other words, 67% of those accidents had happened in the specific sea-areas of Cyclades, Argo-Saronic Gulf, Evoikos Gulf,

Corinthian Gulf and Cretan Sea. Consequently, we have drawn our attention on the strongest rules which had covered the majority of cases and focused on the combination of initial cause of accident and the relevant geographical region. In particular, the CYCLADES sea area is characterized by 17 cases, 60% of those referred to accidents of vessels over 17 years old within the port area on account of weather conditions (as the initial cause). This is mainly attributed to the poor port infrastructure and facilities, i.e. the vessels faced difficulties to execute maneuvers.

In the ARGO-SARONIC GULF sea area, described as sheltered waters, 15 out of 23 cases were due to human error (as the initial cause). The main reason for this finding emanates from the density of traffic, particularly during summer periods, in the wider area where the central port of Piraeus is situated and the structure of the coastal network is depended upon.
In the CORINTHIAN GULF, which are characterized as confined waters, 8 out of 13 cases were attributed to human error (as the initial cause). The examined cases in this sea area refer exclusively to the itinerary Rio – Antirio. The main problem is arising from the degree of difficulty in navigating these special type of ferries, particularly in harsh weather conditions, when approaching both ports.
In the EVOIKOS GULF 6 out of 10 cases were due to equipment failure (as the initial cause). The vessels involved in these short passages between Attica and Evia-island appeared to be very old and poorly operated. Quite recently a proportion of them has been suspended from operations due to ISM requirements.
In the CRETAN SEA 5 out of 7 cases were groundings due to human error (as the initial cause) and have occurred either within port area or in port approaches. The passenger vessels involved in these itineraries are the largest in terms of size.

5. CONCLUSIONS

There is a continuous effort from international bodies to improve safety of passenger ships especially in the last decade. During the last decade, IMO is primarily concerned with large passenger ships' accidents in European waters by enforcing certain technological measures and operational procedures in order to prevent them. Particularly in the Greek sea-areas the well known problems affecting safety of navigation are summarized as

- the long coastline and dispersion of thousands of islands,
- the increased traffic during summer periods, the non-efficiency of lighthouse network,
- the lack of electronic surveillance,
- the lack of traffic separation schemes established on all Greek ports save Piraeus and
- the improper watch on bridge and the inadequate knowledge of existing geographical routes.

Based on results, it is obvious that the initial cause of Greek ships' accidents is attributed to the different characteristics of each geographical region and it is mainly the result of weather conditions and human error. These findings are related to the poor port infrastructure of islands, the immense density of traffic and the centripetal structure of the Greek coastal network having as the center the port of Piraeus.

6. REFERENCES

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