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AN ASSESSMENT OF VESSEL-SOURCE OIL POLLUTION INCIDENTS IN THE MEDITERRANEAN SEA USING INDUCTIVE MACHINE LEARNING METHODOLOGIES

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Abstract. Oil is the pollutant with the longest history of international attention and vessel-source pollution is the most famous internationally regulated area of marine pollution. Ship-related oil pollution is attributed mostly to operational discharges which have consistently overshadowed accidental discharges. Most operational spills stem from ship-routine operations such as loading and discharging of cargoes, receiving bunkers, ballasting and deballasting, tank washing, and are caused by broken hoses, defective valves, overfilling of tanks, leaks from manifold flanges, blowing lines etc, along with the human intervention. Apparently the majority of these incidents happen either close to the mainland or within port areas and terminal stations resulting usually in small spills which are being tackled by the local authorities and are seldom reported. Accidental oil spills are the result of collisions, groundings, explosions, hull and machinery damage, war operations, mixed accidents and generally give rise to severe pollution incidents but are less frequent.

In this paper we analyze 295 cases of ship incidents that caused or likely to cause oil pollution in the Mediterranean Sea during the period 1981-2000. The main source of information has been extracted from the REMPEC database which recorded all the incidents that had occurred in the Mediterranean Sea in the aforementioned period. We attempt to assess the available data with the aid of advanced intelligent techniques, namely machine learning and inductive decision trees. Inductive machine learning is based on entropy information criteria applied to either nominal or numerical data representing database information. The inductive learning methodology is applied for producing automated domain-dependent expert knowledge by mining the data corresponding to ship-incident reports. The outcome of the analysis corresponds to a meaningful set of decision rules, also represented as a top-down classification tree.

1. INTRODUCTION

Oil pollution has been discovered in the late 1940s in the aftermath of the Second World War, when tankers used as naval auxiliary vessels had become the targets of enemy submarines and inevitably sunk in laden condition. In the early 1950s the international community realized, for the first time, the impact of operational pollution, when tankers during ballast voyages began washing their empty cargo tanks and intentionally discharged oil residues to the marine environment (Alexopoulos & Zois, 2002). The floating oil, owing to the prevailing weather conditions, threatened the nearest coasts and the recreational areas.

In contrast, the problem of oil pollution in semi-enclosed seas became quite serious in the last decades (Alexopoulos & Mavranezoulis, 2002). Particularly in the Mediterranean Sea from the late 1970s the possibility of massive oil pollution caused great concern owing to factors such as the sudden increase of oil traffic coupled with the increased size of tankers and other ships either passing through or entering a Mediterranean port, the enlargement of Suez Canal, the development of new oil terminal stations and the advent of offshore oil and gas production. Furthermore, the Mediterranean sea is considered as an area with a high risk of accidental pollution due to the density of traffic, the large number of ports and the existence of a large number of scattered islands and other insular features situated at short distances from international shipping routes.

According to official statistics (ITOPF, 2003) oil inputs to the ocean environment have decreased in recent years due to a decreased frequency of serious ship accidents and spills. However, this is not the picture in regional seas (see table No1). The frequency of the incidents has increased the last years though the spills are relatively minor in terms of cargo quantity lost. Before turning to the analysis of the available statistical data it should be mentioned that, the terms 'incident' and 'accident' often have an overlapping meaning. It has been suggested that 'minor accidents' are usually referred to as incidents. Also an incident is classified as a 'near-miss situation' or a 'near-accident'. For interpretation purposes, an incident is similar to an accident save that it does not involve actual harm to a person, or damage to property or loss to a process (Cremers & Chawla, 1995).

2. ANALYSIS OF SHIP-INCIDENTS IN THE MEDITERRANEAN SEA

It has been acknowledged that, the Mediterranean Sea being no exception to this rule, most oil spills relate to operational discharges from vessels (Alexopoulos, 2001). To that effect, serious tanker accidents (notably spills over 10,000 tons) have not been reported in the Mediterranean Sea during the last decade (1993-2003). This could be explained partly by the effective implementation of the provisions laid down by the MARPOL 1973/78 (according to this convention, the Mediterranean Sea is considered a specially protected area) and the Barcelona regional convention (1976) and partly by the coastal state's strict jurisdiction in case a pollution incident takes place, based on port state control regulations. Unfortunately, other European waters have suffered massive oil pollution, i.e. the recent tanker breakups during stormy weather conditions of *Erika* in the French Atlantic coast (1999) spilling 20,000 tons of oil and of *Prestige* in the northwestern Spanish coast (2002) spilling 77,000 tons of oil.

The database provided by REMPEC includes 311 incidents that have occurred in the Mediterranean Sea and been reported mainly by national authorities (including spills and leakages from industrial plants, refineries, shore terminals, pipelines and underwater hoses) between August 1977 and December 2000. Almost half of these incidents (156) resulted in an oil spill. REMPEC points out that all reported small spills which were not quantified in respective reports, or when the description of the accident indicated that only a small amount of oil was released, were calculated to be of 1 metric ton (or < 1 metric ton).

In our study we have focused only on ship incidents that led to an oil spill or to a near-miss situation. For the *descriptive statistics method* a total of 273 incidents, attached to the period 1981-2000, have been found, 123 of which caused an oil spillage (see tables No1 and No2). This period was chosen due to the availability of the reports. Additionally, a total of 22 incidents were located during the period 1977-1980, 18 of which have caused significant oil pollution, but reporting was inconsistent and uncompleted (in most cases only actual spills were reported). The most serious pollution incidents for the 4-year period were owing to three tanker accidents, the *Juan A. Lavalleja* grounding in 1980 spilling 39,000 tons of crude oil, the *Irenes Serenade* explosion in 1980 spilling almost 80,000 tons of her cargo in Navarino Bay and the *Messiniaki Frontis* grounding in 1979 spilling 14,000 tons of her cargo in Kaloi Limenes (Crete island). However, for the *machine learning method* we have included all 295 cases because we chose to have an integrated view and the best possible experience from analyzing the data despite their shortage.

Table No1

Analysis of ship-incidents causing or likely to cause oil pollution in the Mediterranean sea (recorded during the period 1981-2000)

Year	# of reported incidents to REMPEC	# of incidents that caused oil pollution	# of incidents that did not cause an oil spill
2000	28	7	21
1999	24	8	16
1998	13	6	7
1997	15	5	10
1996	23	7	16
1995	9	3	6
1994	20	8	12
1993	18	9	9
1992	15	12	3
1991	14	10	4
1990	8	6	2
1989	17	10	7
1988	8	4	4
1987	7	4	3
1986	8	3	5
1985	11	4	7
1984	7	5	2
1983	8	3	5
1982	7	2	5
1981	13	7	6
TOTAL	273	123	150

Source: REMPEC database (2001)

By examining the presented data it is obvious that between 1981 and 1993 the number of incidents that resulted in an oil spill is substantially bigger than the number of those that did not cause oil pollution. The next period, 1994-2000 the situation is reversed, although the frequency of reported incidents is higher. Attempting to give an explanation of this picture, reference should be made to the types of accidents. In the first period, spills over 100 tons are attributed to collisions, fire/explosion, contacts and terminal operations whereas in the second period grounding, contact and collision are the primary causes for the oil spill. It is worth noting that no spill, even minor, has been reported for almost all fire/explosion incidents during the second period.

This brings us to the real causes of the incidents. We have categorized them in more detail according to specific parameters such as the type of ship and the type of incident that caused an oil spillage. It is obvious that tankers and bulk carriers are responsible for almost 77% of oil spills, the main reasons were attributed to accidents and to the receiving of bunkers.

Table No2

Ship-incidents that caused oil pollution in respect of type of ships and type of incidents

Type of ship	#	%	Cause of incident	#	%
Tanker	64	52	Terminal operation	32	26
Bulk Carrier	30	24,3	Grounding	22	17,8
Chemical Tanker	7	5,6	Sinking	15	12,1
Container Ship	6	4,8	Collision/ramming	13	10,5
Ro-Ro Ship	5	4	Contact	12	9,7
Other	5	4	Fire/explosion	9	7,3
Passenger Ship	2	1,6	Structural damage	6	4,8
Unknown	2	1,6	Bunkering	6	4,8
			Leakage	4	3,2
			Other	3	2,4
			Unknown	1	0,8

Source: REMPEC database (2001)

In respect of the type of incident "terminal operations" account for 26%. It is noteworthy that almost all cases related to terminal operations resulted in an oil spill (30 out of 32 incidents). These oil spills were due to, almost without exception, deliberate human action or inaction, negligence, ignorance, carelessness and inexperience. IMO estimates that over 90% of all marine pollution incidents is owing to human error and the rest is considered to be due to some technical or mechanical failure, but even that aspect has the human factor as its basis. Leaking of oil was noticed when pipes are ruptured, mooring ropes are broken, pumping operations are taking place, pipelines leaking, hoses being disconnected or parted, faulty valves etc (Gold, 1985).

It is estimated that human error is the real cause for both collisions and groundings. In this study, these accidents seemed to have happened when a vessel was approaching the port rather than leaving it. "Groundings" accounted for 22% and were the result of wrong navigation in congested areas (usually near port entrances) particularly in bad weather conditions, i.e. ropes caught in propellers, vessel detached from her anchors and touching bottom etc. "Collisions" reached 10,5% and were owing to wrong maneuvers while berthing or leaving port or waiting at anchorage.

With regard to "contact" (9,7%) this accident occurred when a vessel hit a permanent object, usually within port limits, i.e. struck a quay while maneuvering, rammed a pier while berthing or rammed a canal's bank or an artificial wave barrier. The majority of "fire and/or explosion" (9%) cases happened in port areas while unloading cargoes and led to a substantial quantity of oil spilled into the sea and to human losses. The ship spaces most vulnerable to fire hazard proved to be the engine room, the boiler room and the accommodation room (Alexopoulos *et al.*, 2002). Finally, "sinking" (12,1%) was attributed to water ingress and heavy damage in shell during stormy weather conditions. These six parameters account for 83.4% of the cases leading to an accident or incident.

3. INDUCTIVE LEARNING METHODS

Machine learning is a field dedicated to the development of computational methods underlying learning processes and to applying computer-based learning systems to practical problems (Michalski *et al.*, 1998). A significant part of research in machine learning has been concerned with developing methods for determining general descriptions of concepts from examples. Usually, machine-learning techniques are divided in four different categories, namely supervised learning, unsupervised learning, reinforcement learning and learning by inductive logic programming (Konar, 2000). The most popular of these methods are based in advanced forms of mathematical logic (Kubat *et al.*, 1998), or in entropy information based techniques (Quinlan, 1993), for generalization, concept description, and classification tasks. The examples used by machine learning schemes, can be expressed in various forms, in particular, in the form of relational data tables, therefore many machine learning methods have an important and direct application to the problems of data mining, that, is, problems of searching for interesting patterns and important regularities in large databases.

Machine learning has proved particularly capable of modeling domains of application having a strong interaction with human experts and influence of human factors. Such application domains are computer assisted medical diagnosis and decision-making, rule-based modeling of control room operator tasks, bio-informatics and DNA sequence data analysis, managerial and financial decision support, problem analysis and forecasting, etc. Particularly challenging, and not yet widely addressed real-world problems, are also those concerned with extracting patterns or rules from text, images or sound sequences.

In this paper we make use of an inductive machine learning methodology, which analyses the data table representing ship accidents, with the aid of entropy information-based criteria. The algorithm named C4.5 was initially proposed by Quinlan, as an improvement of ID3 (Quinlan, 1986), perhaps the most widely known algorithm ever found in the entire machine learning literature, and has now been re-implemented in c-code and in windows environment, by members of the research group supervised by the authors. The algorithm employs a process of constructing a decision tree in a to-down fashion, (Chen, 2000).

A decision tree is a hierarchical representation that can be used to determine the classification of an object by testing its values for certain properties. In a decision tree, a leaf node denotes a decision or classification, while a non-leaf node denotes a property used for decision (such as color, size, etc.). We prefer the shortest path to reach a leaf, because it implies the fewest possible number of questions are needed. The main algorithm is a recursive process that utilizes the examples for constructing the decision tree. At each stage of the process, is selected a property based on the information gain calculated form the training examples. The output of the algorithm in addition to its tree-like representation is also readable as a handy set of independent if-then rules, ready to use in assisting human centered decision-making processes.

4. PRESENTATION AND DISCUSSION OF RESULTS

In order to use the machine learning methodology described above, we attempted a detailed classification of the parameters intended for further examination (Alexopoulos *et. al.*, 2001). The basis of the analysis has been the parameter entitled "type of accident" (see table No2) and the rest of the parameters involved, were the "type of ship", "the area of the incident" and the "type of cargo". There were 295 cases examined and the main attribute being whether an oil spill occurred or not. The parameter "type of ship" includes 7 extra cases referring to tug boats, bunker ships, barges, fishing vessels, Ore/Oil ships, Ore/Bulk/Oil ships and a US Navy vessel. The parameter "flag of the vessel" is subdivided into four categories, namely flags of convenience, traditional registries, offshore registries and international registries.

Three different periods have been identified for better results of the analysis relating to the parameter "date of the incident", notably 1977-1985, 1986-1994 and 1995-2003. Furthermore, the parameter "area of the incident" is related to the position of the vessel at the time of the incident, namely port limits (including congested areas, i.e. canals, straits, anchorages etc), coastal zone (near the coastline of the mainland or an island) and open sea. Finally, the parameter "oil spill lost" (in tons) has been characterized under the headings, none reported, low, medium, high and unknown.

Table No3 summarizes the accuracy obtained from the application of inductive machine learning in the ship accident data set consisting of 295 cases totally. The table also indicated correct and incorrect classification of the training cases. Only one case was considered adequate for forming a decision rule on ship accidents. This corresponds to the most detailed decision tree that can be obtained from the training data. The output was produced in both, a decision tree scheme, and a rule set.

According to table No3, the accuracy of the model corresponding to the training set exceeds 85% ranging from 85.1% (rulesets) to 87.1% (decision tree). The size of the decision tree is 214 nodes and the total number of examples misclassified according to the decision tree produced, is 38 out of 295 cases in total. The size of the rule-set model is 72 rules, each one consisting of two (2) to five (5) premise parts. Errors in classification increase to 44 out of 295 when the acquired rule-set model is tested. The reader should observe that most of the misclassifications appear in those classes formed by a relatively small number of cases (i.e. classes "b" to "e"). Class "a" which covers more than 50% of the total number of training cases, is described almost perfectly (only one [1] misclassification has been made, that is more than 99% accuracy is obtained for cases of this class. The misclassifications for the rest of the classes occur to class "a" i.e. the proposed model is robust for class a, but somewhat weak for the rest of the classes. Observing though that, none out of the two (2) in total cases of class "c" is classified correctly, only 8 out of 14 cases of class "e" are classified correctly, about 42 out of 62 cases of class "c" are classified correctly, and 52 out of 67 cases of class "a" are classified correctly (!) The above situation clearly indicates a linear (or even exponential) growth of the accuracy rate per class of our model, as the number of available cases per class increases.

Table No3
Classification results (overall accuracy and types of misclassification)

Evaluation on training data (295 cases):

Decision Tree		**Rules**	
Size	*Errors*	*No*	*Errors*
214	38 (12.9%)	73	44 (14.9%)

(a)	**(b)**	**(c)**	**(d)**	**(e)**	**<-classified as**
149			1		**(a):** class None_Reported
12	**52**		3		**(b):** class Low
2					**(c):** class Unknown [N-A]
12	7		**42**	1	**(d):** class Medium
4	2			**8**	**(e):** class High

Below we have cited two of the rules induced by the application of the inductive machine learning system to the ship accident dataset:

Rule 7: (cover 19)

DATE_OF_ACCIDENT = Year_86-94
TYPE_OF_ACCIDENT = Fire_explosion
THEN class None_Reported [0.857]

Rule 8: (cover 14)

FLAG = TRADITION_REG
AREA_OF_ACCIDENT = Coastal_zone
TYPE_OF_ACCIDENT = Fire_explosion
THEN class None_Reported [0.813]

Rule Nr. 7 states that if the accident happened between 1986 and 1994 and the type of accident was fire and/or explosion, the there was no pollution reported. This is a conclusion verified in 19 (out of 295) cases of accidents analyzed in total. In other words, most of the accidents that were due to fire explosion in the late 1980's to early 1990's, did not cause any reported pollution. The number indicated in brackets on the right of the rule means that there is 85.7% probability of correct classification of a new case in the future, if the case confirms the above rule Nr.7.

Similarly, Rule Nr. 8 states that if the ship in accident is registered in a traditional flag and the accident took place in the coastal zone and the type of accident was fire and/or explosion, then there was no pollution reported again. This rule is confirmed by 14 cases (approximately 5% of the total number of accidents) and there is 81.3% probability of correct classification of a new case in the future, if the case confirms rule Nr.8. Cross-validation accuracy of the model (1 to 10 folds were used in the related experiments) showed a satisfactory performance of our model when coping with new unseen cases, ranging from 70-80%.

Conclusions

Attempting to discuss briefly the results of the machine learning system we may state that, in respect of *terminal operations* there is almost in every case an oil spill involved throughout the whole period of examination but, the quantities spilled were usually small (see in appendix rules 26, 36, 37, 42, 48, 60, 61, 70 and 71). *Collisions* were either resulting in serious oil spills or no spill reported particularly in recent years (see rules 13, 18, 32, 50, 56, 58, 67, 69 and 73). On the contrary, *groundings* had caused average oil spills in recent years (see rules 24, 30, 35, 43, 46, 52, 55, 59 and 66).

Most *sinkings* had led to either low or average oil spills depending on whether the vessel was in a laden condition or in ballast (see rules 19, 21, 33, 44, 51 and 57). *Contacts* had resulted in almost all cases to an oil spill (see rules 27, 28, 38, 40, 53, 54 and 64), *hull failures* contributed to small spills (see rules 34 and 63) and *fire or explosion* surprisingly had shown only a few cases with a serious oil spill whereas the majority of them did not cause an oil spillage (see rules 2, 5, 7, 9, 11, 12).

Summarizing, the paper proposes the use of advanced computational intelligent techniques for the effective analysis of data representing ship accident information over a long period of time. Inductive machine learning has been selected as a representative intelligent technique for data analysis, generalization and knowledge extraction from historical data, particularly famous for producing meaningful and comprehensive results over domains described by nominal and/or numerical data. Nearly 300 ship incidents that caused, or likely to cause oil pollution in the Mediterranean Sea during the last 25 years, were used as a sample dataset. The accuracy of the rule-based model obtained within the paper, seems encouraging for further use of the methods in similar datasets.

Nevertheless, the main aim of the authors within the paper has always remained to point out new effective ways of analyzing complex data in shipping accident analysis, rather than competitively testing alternative approaches and ways of experimentation over a well-defined dataset. A detailed collection of a larger number of shipping accidents worldwide, would possibly lead to the extraction of useful domain knowledge on shipping accidents and perhaps a guide consisting of fundamental rules for avoiding trivial shipping accidents in the future.

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APPENDIX I

The Entire Ruleset

Rule 1: (cover 10)
IF TYPE_OF_ACCIDENT = Mechanical_failure THEN class None_Reported [0.917]
Rule 2: (cover 8)
IF TYPE_OF_ACCIDENT = Fire THEN class None_Reported [0.900]
Rule 3: (cover 7)
IF TYPE_OF_ACCIDENT = Bad_weather THEN class None_Reported [0.889]
Rule 4: (cover 6)
IF TYPE_OF_SHIP = OBO THEN class None_Reported [0.875]
Rule 5: (cover 14)
IF DATE_OF_ACCIDENT = Year_95-03 AND TYPE_OF_ACCIDENT = Fire_explosion THEN class None_Reported [0.875]
Rule 6: (cover 5)
IF TYPE_OF_ACCIDENT = War_operations THEN class None_Reported [0.857]
Rule 7: (cover 19)
IF DATE_OF_ACCIDENT = Year_86-94 AND TYPE_OF_ACCIDENT = Fire_explosion THEN class None_Reported [0.857]
Rule 8: (cover 4)
IF AREA_OF_ACCIDENT = Coastal_zone AND TYPE_OF_CARGO = Passengers THEN class None_Reported [0.833]
Rule 9: (cover 14)
IF FLAG = TRADITION_REG AND AREA_OF_ACCIDENT = Coastal_zone AND TYPE_OF_ACCIDENT = Fire_explosion THEN class None_Reported [0.813]
Rule 10: (cover 3)
IF TYPE_OF_SHIP = MT AND AREA_OF_ACCIDENT = Coastal_zone AND TYPE_OF_CARGO = Chemicals THEN class None_Reported [0.800]
Rule 11: (cover 3)
IF TYPE_OF_ACCIDENT = Explosion THEN class None_Reported [0.800]
Rule 12: (cover 27)
IF AREA_OF_ACCIDENT = Port AND TYPE_OF_ACCIDENT = Fire_explosion THEN class None_Reported [0.793]
Rule 13: (cover 18)
IF DATE_OF_ACCIDENT = Year_95-03 AND TYPE_OF_ACCIDENT = Collision THEN class None_Reported [0.750]
Rule 14: (cover 2)
IF TYPE_OF_SHIP = Tug THEN class None_Reported [0.750]
Rule 15: (cover 2)
IF AREA_OF_ACCIDENT = Port AND TYPE_OF_CARGO = Iron THEN class None_Reported [0.750]
Rule 16: (cover 5)
IF FLAG = OFFSHORE_REG THEN class None_Reported [0.714]
Rule 17: (cover 8)
IF TYPE_OF_SHIP = Chem_T AND FLAG = FLAG_CONVEN THEN class None_Reported [0.700]
Rule 18: (cover 1)

IF TYPE_OF_SHIP = MV AND AREA_OF_ACCIDENT = Port AND TYPE_OF_ACCIDENT = Collision THEN class None_Reported [0.667]

Rule 19: (cover 1)
IF AREA_OF_ACCIDENT = Coastal_zone AND TYPE_OF_ACCIDENT = Sinking AND TYPE_OF_CARGO = Containers THEN class None_Reported [0.667]

Rule 20: (cover 4)
IF FLAG = INTERN_REG THEN class None_Reported [0.667]

Rule 21: (cover 1)
IF TYPE_OF_ACCIDENT = Sinking AND TYPE_OF_CARGO = Vehicles THEN class None_Reported [0.667]

Rule 22: (cover 1)
IF TYPE_OF_SHIP = Bunker THEN class None_Reported [0.667]

Rule 23: (cover 1)
IF TYPE_OF_ACCIDENT = Bunkering AND TYPE_OF_CARGO = Crude_oil THEN class None_Reported [0.667]

Rule 24: (cover 74)
IF TYPE_OF_ACCIDENT = Grounding THEN class None_Reported [0.605]

Rule 25: (cover 3)
IF DATE_OF_ACCIDENT = Year_77-85 AND AREA_OF_ACCIDENT = Coastal_zone AND TYPE_OF_CARGO = Oil THEN class Low [0.800]

Rule 26: (cover 2)
IF TYPE_OF_SHIP = MV AND TYPE_OF_ACCIDENT = Terminal_operation THEN class Low [0.750]

Rule 27: (cover 2)
IF FLAG = TRADITION_REG AND TYPE_OF_ACCIDENT = Contact AND TYPE_OF_CARGO = Oil THEN class Low [0.750]

Rule 28: (cover 2)
IF TYPE_OF_SHIP = Chem_T AND TYPE_OF_ACCIDENT = Contact THEN class Low [0.750]

Rule 29: (cover 9)
IF TYPE_OF_ACCIDENT = Bunkering THEN class Low [0.727]

Rule 30: (cover 1)
IF TYPE_OF_ACCIDENT = Grounding AND TYPE_OF_CARGO = Vehicles THEN class Low [0.667]

Rule 31: (cover 1)
IF AREA_OF_ACCIDENT = Port AND TYPE_OF_CARGO = Passengers THEN class Low [0.667]

Rule 32: (cover 1)
IF TYPE_OF_SHIP = Chem_T AND DATE_OF_ACCIDENT = Year_77-85 AND TYPE_OF_ACCIDENT = Collision THEN class Low [0.667]

Rule 33: (cover 1)
IF AREA_OF_ACCIDENT = Port AND TYPE_OF_ACCIDENT = Sinking AND TYPE_OF_CARGO = Containers THEN class Low [0.667]

Rule 34: (cover 13)
IF TYPE_OF_ACCIDENT = Hull_failure THEN class Low [0.667]

Rule 35: (cover 1)
IF FLAG = FLAG_CONVEN AND TYPE_OF_ACCIDENT = Grounding AND TYPE_OF_CARGO = Containers THEN class Low [0.667]

Rule 36: (cover 1)

IF TYPE_OF_ACCIDENT = Terminal_operation AND TYPE_OF_CARGO = Chemicals THEN class Low [0.667]

Rule 37: (cover 1)
IF DATE_OF_ACCIDENT = Year_86-94 AND AREA_OF_ACCIDENT = Coastal_zone AND TYPE_OF_ACCIDENT = Terminal_operation THEN class Low [0.667]

Rule 38: (cover 1)
IF TYPE_OF_SHIP = MV AND DATE_OF_ACCIDENT = Year_95-03 AND TYPE_OF_ACCIDENT = Contact THEN class Low [0.667]

Rule 39: (cover 1)
IF TYPE_OF_SHIP = MT AND DATE_OF_ACCIDENT = Year_77-85 AND TYPE_OF_ACCIDENT = Contact THEN class Low [0.667]

Rule 40: (cover 1)
IF TYPE_OF_SHIP = Barge AND TYPE_OF_ACCIDENT = Contact THEN class Low [0.667]

Rule 41: (cover 1)
IF FLAG = TRADITION_REG AND DATE_OF_ACCIDENT = Year_77-85 AND AREA_OF_ACCIDENT = Port AND TYPE_OF_CARGO = Ballast THEN class Low [0.667]

Rule 42: (cover 9)
IF TYPE_OF_SHIP = MT AND DATE_OF_ACCIDENT = Year_77-85 AND TYPE_OF_ACCIDENT = Terminal_operation THEN class Low [0.636]

Rule 43: (cover 3)
IF TYPE_OF_SHIP = MT AND DATE_OF_ACCIDENT = Year_95-03 AND AREA_OF_ACCIDENT = Coastal_zone AND TYPE_OF_ACCIDENT = Grounding AND TYPE_OF_CARGO = Oil THEN class Low [0.600]

Rule 44: (cover 15)
IF FLAG = TRADITION_REG AND TYPE_OF_ACCIDENT = Sinking THEN class Low [0.529]

Rule 45: (cover 2)
IF TYPE_OF_CARGO = Seeds THEN class Low [0.500]

Rule 46: (cover 10)
IF AREA_OF_ACCIDENT = Coastal_zone AND TYPE_OF_ACCIDENT = Grounding AND TYPE_OF_CARGO = Oil THEN class Low [0.500]

Rule 47: (cover 2)
IF DATE_OF_ACCIDENT = Year_77-85 AND AREA_OF_ACCIDENT = Port AND TYPE_OF_CARGO = Ballast THEN class Low [0.500]

Rule 48: (cover 3)
IF DATE_OF_ACCIDENT = Year_95-03 AND TYPE_OF_ACCIDENT = Terminal_operation AND TYPE_OF_CARGO = Crude_oil THEN class Medium [0.800]

Rule 49: (cover 3)
IF TYPE_OF_SHIP = Cont AND DATE_OF_ACCIDENT = Year_86-94 THEN class Medium [0.800]

Rule 50: (cover 2)
IF TYPE_OF_SHIP = MV AND DATE_OF_ACCIDENT = Year_77-85 AND TYPE_OF_ACCIDENT = Collision THEN class Medium [0.750]

Rule 51: (cover 2)
IF TYPE_OF_ACCIDENT = Sinking AND TYPE_OF_CARGO = Oil THEN class Medium [0.750]

Rule 52: (cover 2)
IF TYPE_OF_ACCIDENT = Grounding AND TYPE_OF_CARGO = Minerals THEN class Medium [0.750]
Rule 53: (cover 2)
IF TYPE_OF_SHIP = MV AND DATE_OF_ACCIDENT = Year_77-85 AND TYPE_OF_ACCIDENT = Contact THEN class Medium [0.750]
Rule 54: (cover 2)
IF TYPE_OF_SHIP = Ro_Ro AND TYPE_OF_ACCIDENT = Contact THEN class Medium [0.750]
Rule 55: (cover 1)
IF DATE_OF_ACCIDENT = Year_86-94 AND AREA_OF_ACCIDENT = Coastal_zone AND TYPE_OF_ACCIDENT = Grounding AND TYPE_OF_CARGO = Crude_oil AND THEN class Medium [0.667]
Rule 56: (cover 1)
IF TYPE_OF_SHIP = Barge AND TYPE_OF_ACCIDENT = Collision THEN class Medium [0.667]
Rule 57: (cover 1)
IF AREA_OF_ACCIDENT = Coastal_zone AND TYPE_OF_ACCIDENT = Sinking AND TYPE_OF_CARGO = Iron THEN class Medium [0.667]
Rule 58: (cover 1)
IF TYPE_OF_SHIP = MV AND DATE_OF_ACCIDENT = Year_86-94 AND AREA_OF_ACCIDENT = Coastal_zone AND TYPE_OF_ACCIDENT = Collision THEN class Medium [0.667]
Rule 59: (cover 1)
IF TYPE_OF_SHIP = MT AND FLAG = TRADITION_REG AND DATE_OF_ACCIDENT = Year_86-94 AND AREA_OF_ACCIDENT = Coastal_zone AND TYPE_OF_ACCIDENT = Grounding AND TYPE_OF_CARGO = Oil THEN class Medium [0.667]
Rule 60: (cover 16)
IF TYPE_OF_SHIP = MT AND DATE_OF_ACCIDENT = Year_86-94 AND AREA_OF_ACCIDENT = Port AND TYPE_OF_ACCIDENT = Terminal_operation THEN class Medium [0.667]
Rule 61: (cover 1)
IF TYPE_OF_SHIP = Chem_T AND DATE_OF_ACCIDENT = Year_77-85 AND TYPE_OF_ACCIDENT = Terminal_operation THEN class Medium [0.667]
Rule 62: (cover 1)
IF TYPE_OF_SHIP = O_O THEN class Medium [0.667]
Rule 63: (cover 1)
IF TYPE_OF_ACCIDENT = Hull_damage THEN class Medium [0.667]
Rule 64: (cover 4)
IF TYPE_OF_SHIP = MT AND DATE_OF_ACCIDENT = Year_86-94 AND TYPE_OF_ACCIDENT = Contact THEN class Medium [0.667]
Rule 65: (cover 1)
IF TYPE_OF_SHIP = US_Navy THEN class Medium [0.667]
Rule 66: (cover 1)
IF DATE_OF_ACCIDENT = Year_77-85 AND AREA_OF_ACCIDENT = Port AND TYPE_OF_ACCIDENT = Grounding AND TYPE_OF_CARGO = Crude_oil THEN class Medium [0.667]
Rule 67: (cover 4)

IF DATE_OF_ACCIDENT = Year_86-94 AND AREA_OF_ACCIDENT = Port AND TYPE_OF_ACCIDENT = Collision THEN class Medium [0.667]

Rule 68: (cover 2)
IF TYPE_OF_CARGO = Seeds THEN class Medium [0.500]

Rule 69: (cover 3)
IF DATE_OF_ACCIDENT = Year_86-94 AND AREA_OF_ACCIDENT = Coastal_zone AND TYPE_OF_ACCIDENT = Collision AND TYPE_OF_CARGO = Crude_oil THEN class High [0.800]

Rule 70: (cover 1)
IF DATE_OF_ACCIDENT = Year_95-03 AND TYPE_OF_ACCIDENT = Terminal_operation AND TYPE_OF_CARGO = Oil THEN class High [0.667]

Rule 71: (cover 1)
IF TYPE_OF_SHIP = Chem_T AND FLAG = TRADITION_REG AND DATE_OF_ACCIDENT = Year_86-94 AND TYPE_OF_ACCIDENT = Terminal_operation THEN class High [0.667]

Rule 72: (cover 1)
IF DATE_OF_ACCIDENT = Year_77-85 AND AREA_OF_ACCIDENT = Port AND TYPE_OF_CARGO = Chemicals THEN class High [0.667]

Rule 73: (cover 3)
IF TYPE_OF_SHIP = MT AND DATE_OF_ACCIDENT = Year_77-85 AND TYPE_OF_ACCIDENT = Collision THEN class High [0.600]