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# Analysis of accidents in Greek shipping during the pre- and post-ISM period

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ABSTRACT

In shipping, safety depends on the reliability of the technical and human components of the ship-system, although the marine environment itself may sometimes be so hostile as to give rise to accidents that are beyond technical and human control. The need for a continuous analysis of shipping accidents is dictated by the accumulated evidence for the predominance of the human factor and the ever-increasing pressure for further improvement on the safety record of shipping. In this context, the effectiveness of enforced regulations towards the promotion of safety policy in shipping is assessed and the debate and focus on this issue are maintained.

The purpose of this paper is to examine human reliability with reference to all accidents involving Greek-flagged ships during 1993–2006, a time-scale that spans over the pre- and post-ISM period. The accident data were processed through a decision tree analysis, which enabled the classification of various accident factors, which, for the purpose of this approach, were treated as the tree variables. In the context of assessing the effectiveness of the implemented ISM Code, the above-mentioned analysis revealed that although the human element maintained its dominance in shipping accidents, there is also substantial evidence in support of its effective control during the post-ISM period, since the implementation of the ISM Code led to an overall reduction of human-induced accidents. Furthermore, the ISM Code was found to remove the influence of vessel type upon the human or non-human source of accidents, since prior to ISM implementation tankers and Ro-Pax vessels were profoundly linked to human-induced accidents. In terms of location, the ISM Code improved the human-induced accident record in both navigational regions of restricted and open waters. However, its impact in terms of location was less effective, since the navigation in restricted waters proved to be distinctively linked to human-induced accidents in comparison to that of open waters, over the entire period of investigation.



## 1. Introduction

According to the International Maritime Organisation (IMO) ‘the human element is a complex multi-dimensional issue that affects maritime safety and marine environmental protection. It involves the entire spectrum of human activities performed by ships’ crews, shore-based management, regulatory bodies, recognised organisations, shipyards, legislators, and other relevant parties, all of whom need to cooperate to address human element issues effectively’.[1] The UK Marine Accident Investigation Branch (MAIB) states that ‘one factor still dominates the majority of maritime accidents: human error’ [1]. The ‘human element’, as it is often termed in the shipping literature [2], has frequently been cited as an immediate cause (or source) of these costly incidents. On the other hand, the technological component of shipping raises the issue of technical reliability in shipping [3] and most importantly that of human factors [4] and the onboard man–machine interface [5].

Research within the human element domain, apart from producing the statistics of human influence upon shipping accidents, has also focussed on providing the knowledge of ‘why people make mistakes’, thus proposing appropriate remedial action. Most of the initial research effort concentrated on demonstrating that shipping is a ‘people system’ and should be treated as such [6]. This approach was also justified by the realisation that the relative impact of human error as an underlying source of accidents acquired increasing importance as various technical (structural and equipment) improvements were producing the expected safety benefits.

Consequently, the need to introduce a human-centered safety policy in shipping became imperative and the appropriate legislative measure was enforced in mid-1998, with the implementation of the International Safety Management Code (ISM Code), meaning the International Management Code for the Safe

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[1] http://www.imo.org/HumanElement/mainframe.asp?topic_id=177.

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Operation of Ships and for Pollution Prevention. The objectives of this Code are:

> to ensure safety at sea, prevention of human injury or loss of life, and avoidance of damage to the environment, in particular to the marine environment and to property. Safety management objectives of the Company should, inter alia:

- Provide for safe practices in ship operation and a safe working environment;
- Establish safeguards against all identified risks; and
- Continuously improve safety management skills of personnel ashore and aboard ships, including preparing for emergencies related both to safety and environmental protection.[2]

However, the nature of such a measure is relatively sluggish, since it relies on the expectation of change in behaviours, attitudes, etc. and generally on a shift to a quality culture by everyone involved in the shipping system. On the other hand, the pressure for continuous improvement of shipping safety dictates the need for prompt and reliable assessment of the implemented safety policy measures. The reliability of this assessment is mainly dependent upon the external (as opposed to the internal or in-house) nature of auditing and investigation. The two approaches that mainly qualify for this type of ISM Code assessment are those of shipping accidents analysis and inspection record analysis.

With respect to the former approach, previous research in this area [7] provides an in-depth analysis of the human element as a factor in Greek shipping accidents during the 1984–1994 period and in conclusion it comments

> It is impossible to tell for each of the cases reviewed that the accident would not have occurred if ISM were in place for the ship in question. It is also early to assess the impact of ISM on the safety of the ships on which the Code has been implemented. This will take years to ascertain, and the analysis to do so will not be trivial. However, the very fact that ISM certification implies that all procedures related to the operation of the ship would at least be established, monitored and controlled, means that the risk of a situation getting out of hand would be minimised.

The alternative approach towards the assessment of the ISM Code relies upon the records of vessel detentions and deficiency notices produced within the framework of inspections performed by Memoranda of Understanding (MoUs) on Port State Control (PSC).[3] In 2007, Paris MoU conducted a Concentrated Inspection Campaign (CIC) focusing on the effective implementation of the ISM onboard and the findings showed that the ISM system is starting to work.[4]

However, in October 2007, another project attempted to establish the influence of ISM implementation, by assessing the statistical differences in the published records of inspections, deficiencies and vessel detentions. Reported on at the IMO MSC84 sessions in May 2008, this project revealed that comparable data on the effectiveness of the ISM Code are not as straightforward as they should be, due to the presence of inconsistencies in reporting and administration between different MoUs, as well as amongst the signatory nations of each MoU. Furthermore, it was remarked that recorded deficiencies (and especially those of ISM relevance), being the result of a PSC inspector's opinion, are easily influenced by a host of subjective issues, such as the attitude of the crew, the ease of inspection, the inspector's mood, etc.[5]

The current work attempts an external assessment of the ISM Code over a time frame that captures the pre- and post-ISM picture of the dependency of shipping safety upon human or non-human sources. To this extent, the information included in official investigation reports of the Hellenic Coast Guard, with regard to accidents of Greek-flagged ships worldwide, over the period of 1993–2006, was utilised. With respect to the choice of flag administration, it is assumed that Greek shipping, by virtue of its size and diversity, constitutes a valuable reference for the analysis of accidents. Since the primary source of information was of textual form, a thorough process of data entry, editing and validation was carried out. This information was transformed and coded in order to produce the dataset upon which the classification tree analysis was performed [8].

The analysis applies an algorithm in order to produce an optimal classification rule and is trained to classify the cases of a dataset (in this case that of shipping accidents) to certain categories of a target-dependent variable using the information of several predictive variables. The generated classification tree relates the categories of the dependent variable to its predictors [9]. More specifically, it provides the ability to detect and estimate the dependency of the source of accidents (human or non-human) upon the period of accident, the vessel (ship) type, size and age, the location of accident, the cause of accident (grounding, explosion/fire, technical failure), etc.

## 2. Methodology

### 2.1. The accident dataset

In terms of the accident information under analysis, it is important to note that the prerequisites for the launch of a formal investigation by the Hellenic Coast Guard are any of the following:

- Total or partial loss of a ship or floating structure.
- Ship or floating structure is taken over by insurers.
- Permanent or temporary abandonment of ship by the crew.
- Cargo loss or failure (more than 25%).
- Prolonged loss of ship command due to serious failure.
- Loss of life or serious injury to a crew member or passenger.

For the purpose of the current analysis all accidents involving vessels under 500 grt were discarded, since ships of this size have been exempted from ISM Code compliance. Subsequently, data cleaning was applied in order to eliminate cases with identical accident information, missing values and unreliable data [10]. On the basis of all the above-mentioned criteria, the accident dataset consisted of 268 shipping accidents.

[2] See footnote 1.

[3] Port State Control (PSC) is the inspection of foreign ships in national ports to verify whether the condition of the ship and its equipment complies with the requirements of international regulations and that the ship is manned and operated in compliance with these rules. IMO has encouraged the establishment of regional port State Control organisations and agreements on port State Control (MOUs) have been signed covering all of the world's oceans.

[4] The report of the Paris MoU CIC on the implementation of the ISM Code carried out in September, October and November of 2007 was presented to PSCC41. The results will be also presented to IMO in 2009.

[5] http://maritimemarketresearch.com/Ten%20Years%20of%20ISM.html.

## 2.2. Classification tree analysis

### 2.2.1. Classification algorithm

The analysis is based on a classification tree algorithm known as CHAID [11]. CHAID analyses a single attribute of a population (the dependent variable) based on other attributes (predictor variables). CHAID is an iterative technique that examines the predictors (e.g. classification variables) individually and utilises them in the order dictated by their statistical significance. For example, if the analysis found that the ship's size is the best variable for distinguishing among human or non-human source accidents, the population (of accidents) is divided using the significant ship size groups. The process is continued until all variables have been examined. Those that are significant trigger another division of the data; those that are not significant are discarded for that partition.

CHAID involves a sophisticated application of the basic $\chi^2$ Contingency Test introduced in every basic statistics course. $\chi^2$ was used as an impurity measure because of a categorical-dependent variable. CHAID determines the best split at each node by merging pairs of categories of the predictor variable with respect to their distance from the dependent variable. The $\chi^2$ test measures this distance. It produces non-binary classification trees and assumes scale and ordinal or nominal types in the predictor variables. Classification trees are also directly compared to other traditional statistical methods. They have less-stringent requirements as it assumes no linearity of relationship between the independent variables and the dependent and not normally distributed variables [12].

The validation of the resulting tree diagram by an expert, and its calibrated form, is generally acknowledged as the second more important element of the process, following undoubtedly the effort of the data cleaning and validation process.

### 2.2.2. Variables

The variable 'Source of Accidents' for this analysis is the variable that is thought to be dependent upon the predictor variables, which are 'Cause of Accident', 'Vessel Tonnage', 'Vessel Type', 'Vessel Age Group', 'Location' (of accident) and 'Period of Accident'.

The dependent variable 'Source of Accident' is defined as a dichotomous variable accepting values of human or non-human, with 57.1% and 42.9%, respectively. These values represent the conclusion of the reports based on the formal investigation of the shipping accidents, with regard to whether a human entity (Ship's Master or 1st Engineer, Pilot, Offshore Personnel, etc.) was ultimately responsible for the accident or otherwise (Random Event, Act of God, Unidentified Source). As an indication of human source analysis, it is important to mention that the ship's master was found to be responsible for 41% of all accidents and for 72% of all human-induced accidents.

Of all the predictors, the 'Period of Accident' (pre-ISM or post-ISM, with 44.4% and 55.6% of accidents, respectively) acts as the main experimental conditioning variable. This is the variable of the experimental hypothesis intended to measure the pattern of effects before and after the ISM legislation was enforced. The list of dependent and independent variables is shown in Table 1.

The variable 'Location' (of accident) is related to the position of the vessel at the time of the accident, namely restricted waters (ports, canals, straits, anchorages, coastal waters, etc.) and open sea, with 58.6% and 41.4%, respectively. Furthermore, the variable 'Vessel Tonnage' ranges between 488 and 132 590 grt, with a standard deviation of 17 296 and a mean value of 13 040 grt.

The frequencies and percentage share of the predictor variables 'Vessel Type', 'Vessel Age Group' and 'Cause of Accident' are shown in Table 2.

### 2.2.3. Algorithm specifications

The specification parameters for the CHAID algorithm are shown in Table 3.

**Table 1**
List of dependent and independent variables.

| Variable label | Measure |
|---|---|
| Source of accident (human or non-human) | Dependent |
| Cause of accident | Predictor |
| Vessel tonnage (grt) | Predictor |
| Vessel type | Predictor |
| Vessel age group | Predictor |
| Location (of accident) | Predictor |
| Period of accident (pre-ISM or post-ISM) | Predictor (main experimental) |

**Table 3**
Specification parameters of CHAID algorithm.

| | |
|---|---|
| CHAID | |
| ALPHASPLIT = 0.05 | $p$-value of split |
| ALPHAMERGE = 0.05 | $p$-value of split |
| CHISQUARE = PEARSON | Statistical test for splitting |
| CONVERGE = 0.001 | Stopping rule |
| MAXITERATIONS = 100 | Stopping rule |
| ADJUST = BONFERRONI | How categories of can be merged |
| INTERVALS = 10 | Discretisation parameter of continuous variables (grt) |
| MINPARENTSIZE = 10 | Split option for the "parent" |
| MINCHILDSIZE = 2 | Split option for the "child" |
| SPLITMERGED = NO | Split option for the merged categories |

**Table 2**
Frequency of 'Vessel Type', 'Vessel Age Group' and 'Cause of Accident'.

| Vessel type | No. | % | Vessel Age Group (years) | No. | % | Cause of Accident | No. | % |
|---|---|---|---|---|---|---|---|---|
| Gen. Cargo ship | 47 | 17.5 | 1–8 | 26 | 9.7 | Grounding | 133 | 49.6 |
| Bulker | 89 | 33.2 | 9–22 | 84 | 31.3 | Tech. failure | 77 | 28.7 |
| Container ship | 13 | 4.9 | 23–26 | 54 | 20.2 | Fire/explosion | 26 | 9.7 |
| Tanker | 56 | 20.9 | 27+ | 104 | 38.8 | Collision | 11 | 4.1 |
| Cruise ship | 4 | 1.5 | – | – | – | Flooding | 15 | 5.6 |
| Ro-Pax | 59 | 22.0 | – | – | – | Other | 6 | 2.2 |
| Total | 268 | 100.0 | Total | 268 | 100.0 | Total | 268 | 100.0 |

*Note*: The Gen. Cargo category of the variable 'Vessel Type' includes three (3) Ro-Ro accidents and the other category of the variable 'Cause of Accident' covers arson, capsize and cargo shift.

## 3. Presentation and discussion of results

The result of the applied classification tree algorithm is shown in Fig. 1. The dependent variable 'Source of Accident' was divided by 57.1% and 42.9% into human and non-human source, respectively. According to this finding, the current work produced a conservative estimate of human element influence upon shipping accidents in comparison to the widely acknowledged 65%. However, it is important to note that this higher estimate is mainly supported by research conducted prior to ISM implementation. Indeed, the argument that the ISM Code altered the level of human influence is validated through the current classification tree analysis, which shows that 63.9% of the pre-ISM accidents were due to human sources, as opposed to the 51.7% during the post-ISM period.

However, most significantly, this result is associated with the main experimental variable 'Period of Accident', which was found to produce the first split of the classification tree (Nodes 1 and 2). The variable 'Period of Accident' is the statistically most significant predictor ($p$-value: $0.045<0.05$) and validates the main experimental hypothesis. The implication of this finding is that the dependent variable 'Source of Accident' (human or non-human) is primarily affected by the predictor variable 'Period of Accident' (pre-ISM or post-ISM); hence the implementation of the

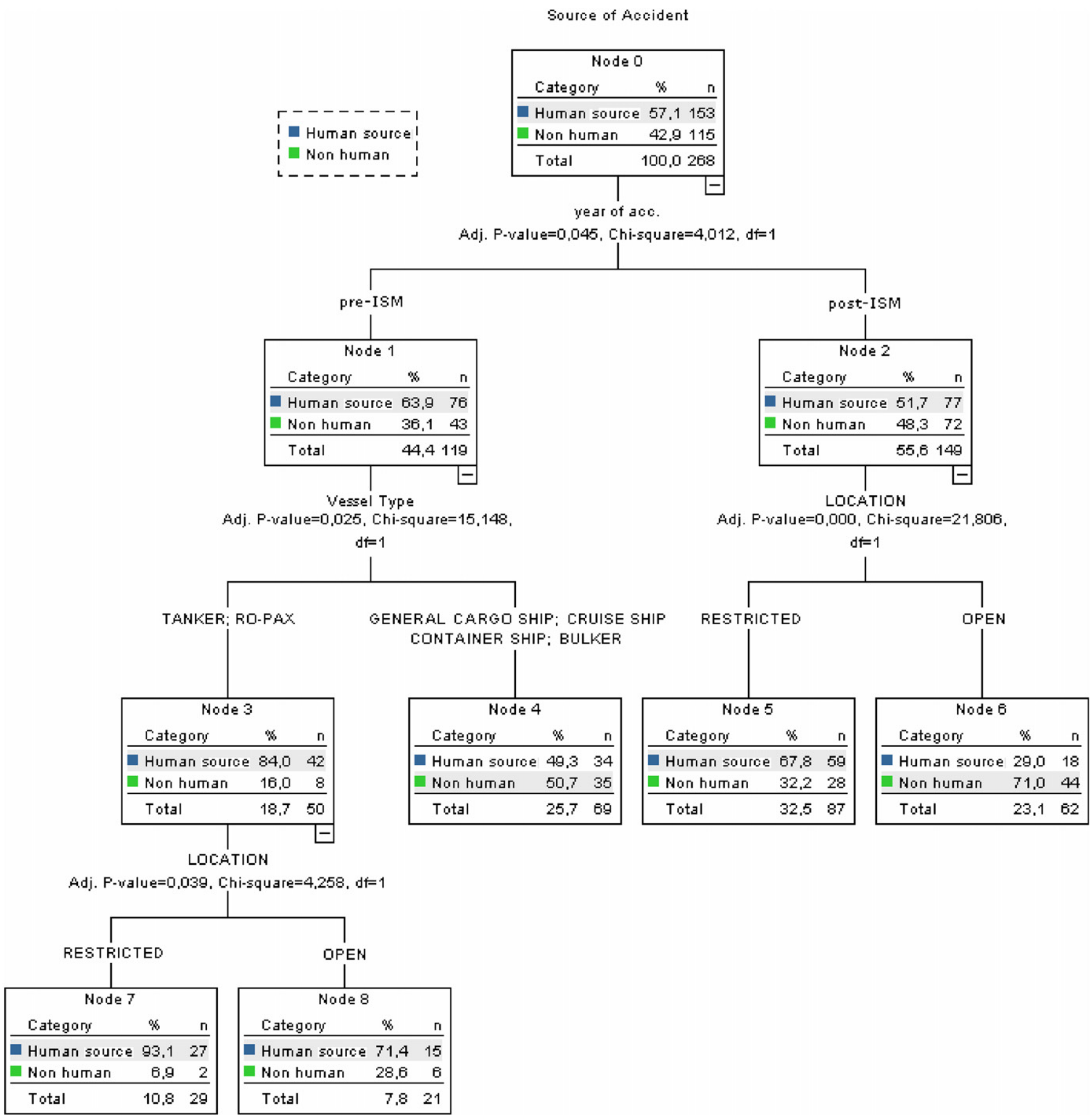


**Fig. 1.** The classification tree for the dependent variable 'Source of Accident'.

ISM Code (in 1998) through its influence upon the human element constitutes the most important feature of the analysed shipping accident record.

Following the demonstration of the prime dependence of the variable 'Source of Accident' (human or non-human) upon the predictor variable 'Period of Accident' (pre-ISM or post-ISM), the classification tree presents its further dependence, as follows.

With respect to the pre-ISM accidents, the predictor variable 'Vessel Type' was found to produce the next split of the classification tree (Nodes 3 and 4); hence the distinct influence of the vessel type categories upon the source of accidents. More specifically, 84% of the pre-ISM tanker and Ro-Pax accidents were due to human sources, as opposed to 49.3% of the human-induced accidents encountered by other vessel types. This finding implies that during the pre-ISM period tankers and Ro-Pax vessels were distinctively more vulnerable to the impact of the human element, in accordance with the increased demand for safety (hence human control) associated with these vessel types. Staying within the domain of the pre-ISM accidents, the predictor variable 'Location' (of accident) was found to produce the next split of the classification tree (Nodes 7 and 8), hence the distinct influence of the location categories upon the source of accidents. According to this split, 93.1% of the pre-ISM tanker and Ro-Pax accidents in restricted waters and 71.4% of those in open waters were attributed to human sources. The higher share of the human-induced accidents within restricted waters is an expected finding due to the acknowledged navigational difficulties experienced within this sea region. In conclusion, the human or non-human source of accidents was found to have no further dependence upon any other predictor variable for the pre-ISM accidents.

Alternatively, along the post-ISM branch of accidents, the predictor variable 'Location' (of accident) was found to produce the first and only split of the classification tree, hence the distinct influence of location upon the source of accidents. More specifically, human sources were accountable for 67.8% of the post-ISM accidents encountered within restricted waters, as opposed to the 29% of the open water accidents. This finding reveals that, despite the ISM Code implementation, navigational location continues to play an important role on the source of shipping accidents and that navigation in restricted waters maintains its higher vulnerability.

The comparison between the pre- and post-ISM period shows that the shipping accidents due to human element were reduced by 12.2%, thus providing evidence of ISM effectiveness. Furthermore, the single dependence of the human or non-human source of post-ISM accidents upon their location indicates that the implementation of the ISM Code withdrew the distinct pre-ISM influence of certain vessel types (tankers and Ro-Pax) upon the human element.

More specifically, during the post-ISM period, the human-induced accidents of tankers and Ro-Pax vessels were reduced by 29.2%, whereas those involving other types of vessels were only reduced by 0.6% (Table 4). On the basis of this finding, the ISM Code led to the balanced and hence no-classifying influence of vessel types. The direction of this convergence towards the balanced influence of vessel types through the reduction of human-induced accidents of tankers and Ro-Pax is also indicative of the comparative effectiveness of the ISM Code towards these types of vessels.

**Table 4**
Vessel type and source of accident for pre- and post-ISM period.

| Period of accident | Vessel type | Source of accident | |
|---|---|---|---|
| | | Human (%) | Non-human (%) |
| Pre-ISM | Other | 49.3 | 50.7 |
| | Tanker and Ro-Pax | 84.0 | 16.0 |
| Post-ISM | Other | 48.7 | 51.3 |
| | Tanker and Ro-Pax | 54.8 | 45.2 |

With respect to accident location, the ability of the classification tree analysis to provide a location split throughout the pre- and post-ISM period indicates that both restricted and open water navigation maintained its influence upon the source of accidents (human or non-human). Furthermore, it was found that restricted navigation produced most human-induced accidents and it continued to do so despite their reduction by 25.3% during the post-ISM period. The overwhelming presence of the pre-ISM human-induced accidents in restricted waters (93.1%) and the difficulties associated with restricted navigation limited the effects of the ISM implementation. On the other hand, after the ISM Code, human-induced accidents in open waters were reduced by 42.4% (from 71.4% to 29.0%, pre- to post-ISM) and ceased to produce the majority of human-induced accidents, an observation that is consistent with the improved effectiveness of the ISM Code within this navigational location.

## 4. Conclusions

The application of a classification tree analysis upon Greek shipping accidents produced a reliable assessment of the ISM Code effectiveness. It was shown that the ISM Code constitutes an effective policy measure for shipping safety, since the source of accidents (human or non-human) was found to be primarily dependent upon the period of accident (pre- or post-ISM). The beneficial influence of the ISM Code was found to stem mainly from its impact upon the control of the human element in tankers and Ro-Pax vessels. During the post-ISM period, the distinct influence of vessel type categories upon the source of accidents was removed through the reduction of human-induced accidents in tankers and Ro-Pax vessels. In this respect, the ISM Code has targeted the most vulnerable vessels in terms of risk of pollution and loss of life, hence proving most successful. Finally, although the ISM Code implementation led to significant reduction of human-induced accidents in both open and restricted waters, it did not remove the influence of navigational location upon the source of shipping accidents (human or non-human). This finding, in conjunction with the persistence of restricted navigation to produce most human-induced accidents, indicates that the expectations of the ISM Code in the domain of navigational location and particularly that of restricted waters have not yet been fully realised.

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