Visualization of Ship Risk Profiles for the Shipping Industry

Sabine Knapp and Michel van de Velden

ERIM Report Series *Research in Management*	
ERIM Report Series reference number	ERS-2010-013-LIS
Publication	March 2010
Number of pages	22
Persistent paper URL	http://hdl.handle.net/1765/19197
Email address corresponding author	vandevelden@ese.eur.nl
Address	Erasmus Research Institute of Management (ERIM) RSM Erasmus University / Erasmus School of Economics Erasmus Universiteit Rotterdam P.O.Box 1738 3000 DR Rotterdam, The Netherlands Phone: + 31 10 408 1182 Fax: + 31 10 408 9640 Email: info@erim.eur.nl Internet: www.erim.eur.nl

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REPORT SERIES
RESEARCH IN MANAGEMENT

ABSTRACT AND KEYWORDS	
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Free Keywords	maritime safety, ship risk profiles
Availability	The ERIM Report Series is distributed through the following platforms: Academic Repository at Erasmus University (DEAR), DEAR ERIM Series Portal Social Science Research Network (SSRN), SSRN ERIM Series Webpage Research Papers in Economics (REPEC), REPEC ERIM Series Webpage
Classifications	The electronic versions of the papers in the ERIM report Series contain bibliographic metadata by the following classification systems: Library of Congress Classification, (LCC) LCC Webpage Journal of Economic Literature, (JEL), JEL Webpage ACM Computing Classification System CCS Webpage Inspec Classification scheme (ICS), ICS Webpage

Visualization of ship risk profiles for the shipping industry

Sabine Knapp[1], Michel van de Velden

Econometric Institute, Erasmus University Rotterdam[2]

Abstract

This article uses correspondence analysis to visualize risk profiles and their changes over the time period 1977 to 2008. It is based on a unique dataset which combines incident data and ship particular data. The risk profiles can help stakeholders better understand the relationship of ship particulars, casualty types, incident locations, loss of life and pollution and link the results to developments of the legislative framework. The results demonstrate that the fleet improved their risk profiles over time reflecting legislative measures, port state control and vetting inspections. Older, general cargo ships flagged by black listed flags are most likely to be wrecked, stranded or grounded and remain risk prone towards flooding, foundering and capsizing. Some trading areas characterized by inter-regional trade operating outside the legislative framework remain risk prone. Most incidents do not involve loss of life or pollution. In terms of absolute figures, high risk prone areas for loss of life are the North and South China Sea, Japan and South Korea, the Mediterranean, Red and Black Sea and the Arabian Gulf. Casualty types which are more likely to lead to higher loss of life are flooding, foundering and capsizing on vessels which are flagged with black listed flags. For pollution, most oil pollution occurred in the area of the British Isles, the North Sea, the English Channel and the Bay of Biscay. High pollution quantities are more likely to be found due to collision and the vessel being wrecked, stranded and grounded than with other casualty types.

[1] Disclaimer: 'The views expressed in this article represent those of the author and do not necessarily represent those of the International Maritime Organization (IMO)

[2] Sabine Knapp. Michel van de Velden, Econometric Institute, Erasmus Univ., P.O. Box 1738, NL-3000 DR, Rotterdam, The Netherlands, knapp@ese.eur.nl or vandevelden@ese.eur.nl

1. Introduction

The shipping industry is regulated by a complicated international legal framework based on more than 50 conventions. The main regulatory bodies are the International Maritime Organization (IMO) and the International Labor Organization (ILO) which is supported by various regional bodies (e.g. EU directive, regulations, Oil Pollution Act in the USA). Sometimes, enforcement can be weak due to the international nature of the legislative framework and the limited ability to control enforcement. In November 2005, IMO developed the Voluntary Member States Audit scheme (VIMSAS) through Assembly Resolution A974(24) [1]. According to the IMO secretariat [2], 45 Member States have volunteers for an audit as of December 2008 and 27 have been audited where 6 audits were complemented by technical assistance following the audit to assist Member States to enhance compliance. While the scheme is to be seen as a non mandatory scheme, it is certainly an important step towards enforcement improvement which will further be enhanced once the scheme will become mandatory as outlined in Assembly Resolution A.1018(26) [3] adopted in November 2009.

The topic of risk analysis is relatively new at IMO level and was first introduced in 2001 when guidelines for *Formal Safety Assessment (FSA)* were approved to be used in the legislative process. While FSA is a systematic process for assessing risk, its application is limited to major changes in the framework due to the complexity and the lack of quality data to conduct risk analysis. At the operational ship level, IMO adopted the *International Safety Management Code (ISM Code)* in 1993 which came into force in July 1998 for passenger vessels, tankers and dry bulk carriers and in July 2002 for all other ship types. The ISM Code introduces the concept of safety management and risk management on an individual ship level.

It is also worth noting that IMO defined a framework which should facilitate measurement of performance of the Organization reflected by its 13 strategic directions and 42 performance indicators (PI) based on Assembly Resolutions A.1011 (26)[4]. The Assembly Resolution was revised in November 2009 and the 42 performance indicators supplemented by additional key performance indicators. The current set of indicators are basic and do not take relationships of variables into account which limits their ability to identify weaknesses in the system. One major area of interest to IMO is to identify the effectiveness of legislative measures in place represented by the major conventions. Knapp and Franses [5] provide an analysis using regression analysis for 45 legislative milestones and conclude that the immediate effect of entry into force presents a mixed picture and most improvement was achieved in areas related to safety management and pollution followed by technical areas.

In the literature, Bijwaard and Knapp [6] demonstrate by means of duration analysis based on a time period of 29 years that the hazard rate is low and that shipping is a relative safe mode of transport given the billions of tones of cargo which are carried by sea each year. Even with small risk involved, an incident[3] can bear substantial economic costs which are difficult to quantity. According to Grey [7], accident related costs translated to USD/tons of oil spilled can vary between USD 667/tons of oil spilled to USD 180,000/tons of oil spilled. Duration analysis also provides some insight into the relationship of ship particulars and their changes over time towards the hazard rate and the probability of survival. Knapp and Franses [8] [9] use binary logistic regression to measure the effect of

[3] The term incident is used to cover incidents, accidents and casualties as per the definition of the International Maritime Organization (IMO)

safety inspections on the probability of casualty and their analysis provides some insight into the importance of ship particulars towards the basis risk profile.

The shipping industry is known to be very conservative in nature and the concept of using statistical analysis for policy decisions or policy evaluations is rather new. While the literature provides inside into the effectiveness of safety inspections and the legislative framework and also demonstrates the importance of ship particulars to identify the basic risk profile, the location of casualties and changes of the risk profiles over time are not taken into consideration. It is also rare to find information on loss of life, pollution quantities and pollution types other than oil pollution. This article tries to fill this gap by visualizing relationships between ship and casualty related variables. Correspondence analysis and joint correspondence analysis are used to produce two dimensional plots that enhance the understanding and interpretation of the relationships for policy makers and insurance companies.

The article is structured as follows. In chapter 2, we present a brief overview of the methods – correspondence and joint correspondence analysis – used in this article. This is followed by an explanation of the various types of variables used for the risk profiles in Chapter 3. Chapter 4 presents and discusses the results and Chapter 5 summarizes the findings.

2. Overview of methods to visualize risk profiles

The aim of this paper is to explore relationships between ship particulars, ship profiles, and casualty data. In this exploration, many variables are involved that possibly interact in some undetermined way. To explore the most important relationships, a visualization method is often useful. Summarizing complex data structures in a graphical display, provides an efficient way for communicating the most important relationships. Correspondence analysis (CA) is a method that is particularly suited for graphical representations of categorical data. In its most basic form, sometimes referred to as simple correspondence analysis (refer to Greenacre [10] for a detailed explanation), rows and columns of a contingency table, that is, a cross-tabulation with counts of co-occurrences for two categorical variables, are depicted in low (usually two) dimensional space. Knapp and Van de Velden [11] used CA in an analysis of port-state control results to analyze differences in treatment of vessels across port state control regimes.

If more than two categorical variables are present, multiple correspondence analysis (MCA) may be used to depict all categories as well as all observations. This is done by applying the simple CA algorithm to a so-called (super)-indicator matrix; a matrix of dummy variables where each column corresponds to one category. One drawback of MCA is that in addition to approximating the relationships between categories of different variables, it also approximates the relationship of categories of the same variable which is in fact nothing else than the approximation of a diagonal matrix consisting of the marginal distribution over the categories. If we are specifically interested in all two-way associations between the categories of the variables, joint correspondence analysis (JCA: Greenacre [10]) overcomes this problem. In JCA, only the contingency tables for all combinations of the variables are jointly approximated in a least-squares sense. This procedure is similar to the approximation of a covariance or correlation matrix in factor analysis. Van de Velden [12] showed that JCA can be seen as multi-group factor analysis of categorical data (van de Velden [12]). Note that, if there are only two categorical variables, JCA and CA (using a symmetrical biplot standardization) are identical.

CA and JCA output is typically a two dimensional plot. However, if the explained variance, or, as it is referred to in CA; inertia, is low and increases considerably by adding dimensions, a solution of higher dimensionality may be chosen. In case of a two dimensional solution, the CA and JCA results can be plotted in a two dimensional map. For CA there are several options on how to do plot row and column points. In this paper, we only use the symmetrical biplot option which corresponds to the scaling used in JCA. This means that both in the CA and JCA plots presented in this paper, associations between categories are represented by considering projections of the categories on each other. For technical details see [10], [12], or [20]. Latter paper also gives details on CA program used for the CA plots. In the JCA and CA plots, categories with similar profiles, i.e. distributions over the other categories, will appear in similar directions. As CA and JCA approximate standardized contingency tables, the projections are approximations of the ratios of observed and expected values (assuming independence) minus 1. Hence, each projection indicates whether the ratio observed/expected is greater or less than unity. In other words, they show, for each combination, whether we observed more or less co-occurrences than expected under independence.

3. Explanation of data and variables used for risk profiles

The analysis is based on a unique dataset of 49,151 observations from various sources from the time period 1977 to 2008[4]. The main data sources for the casualty data are Lloyd's Register Fairplay (LRF), Lloyd's Maritime Intelligence Unit (LMIU) and the International Maritime Organization (IMO). For missing ship particulars at the time of casualty, data from LRF was used to complement it.

Table 1 presents the variable groups such as ship types, age groups, flag groups and classification societies groups. Since ship types reflect the various segments of the industry and its operational characteristics, the ship types are grouped into six major groups. Flag states are classified according to the black/grey/white list of one of the major port state control (PSC) regimes, namely the Paris Memorandum of Understanding [13] and a separate category for unknown flag was added. Port state control regimes are groupings of countries who have agreed to harmonize vessel inspections and ensure a minimum enforcement level of the international legislative framework.

Table 1: Variable grouping for ship particulars

Ship Types	Age Groups	Flag Groups	Class Groups
General cargo (GC)	up to 5 years (<5)	Black	IACS
Dry bulk (DB)	6 to 10 years (6-10)	Grey	NIACS
Container (C)	11 to 15 years (11-15)	White	Undefined (CLUndef)
Tanker (T)	16 to 20 years (16-20)	Unknown (FlUnk)	
Passenger (P)	21 to 25 years (21-25)		
Other (O)	26 to 30 years (26-30)		
	above 30 years (>30)		

Note: Abbreviation used in the plots are given in brackets if different from the abbreviation used

[4] The years 1977 and 2008 are not complete

Most ports are now covered by at least one MoU and there are currently ten regimes in place. Black listed flags perform worse than average while white listed flags perform better and grey lies in the middle. This performance is in relation to safety and environmental aspects of ship operations and reflects the results of inspections performed by the regime.

Classifications societies are organizations who are responsible for the construction and safety management of the vessels. Classification societies can be recognized by flag states and in certain cases, in particular for mandatory surveys, act on behalf of the flag state. In cases like that, they become Recognized Organizations (RO) and one vessel can have multiple RO's depending on the certificate and type of survey which is conducted. It is however difficult to obtain data on the association of a vessel per RO and for the purpose of this article, we only us the traditional role of the classification society. The organizations are grouped according to an important industry grouping which identifies membership to the International Association of Classification Societies (IACS) and are believed to represent a higher level of quality. We therefore group the organization into IACS-recognized (IACS) and IACS-non recognized classification societies (NIACS). A separate category for undefined class is added.

According to the literature, ownership and safety management of a vessel is also an important variable to determine risk profiles. The determination of beneficial ownership is however very complicated due to the international nature of shipping. There is currently no mandatory requirement to identify the beneficial owner but identification is only limited to the registered owner which can be any “brass plate” company. The same applies for indicating safety management although there is a mandatory requirement which will come fully into force in 2010. Safety management is measured via the “Document of compliance company (DoC Company)” according to the ISM Code mentioned previously. Especially the latter is not available for older data. We therefore decided not to take these variables into account and to concentrate on flag and classification society. Both variables could be the subject of future research once better data become available.

While the literature referred to in the introduction of this article covers various aspects of the seriousness of incidents (eg. very serious, serious, less serious), less emphasis is given on the casualty type, in particular in relation to the casualty location. We therefore include this aspect and Table 2 provides a list of the casualty types used in the analysis with their respective abbreviations used in the plots. Under normal circumstances, the distinction between hull related failures and engine related failures is not made by the data provider due to the lack of the quality of the data. In this article however, we provide this distinction and the raw data was analyzed and manually reclassified. In addition, an effort was made to identify the casualty first event when possible and the casualty types classified here provide a more refined classification than normally found. Finally we exclude any unknown categories from the analysis.

Table 3 provides an overview of the incident locations and regions used in the analysis where the raw data contained the longitude and latitude coordinates of the casualty. The coordinates can be classified into the Marsden Grid which divides earth into 100 squares of 10° time 10° squares (North/South and East West)[5]. The Marsden Grid is then grouped into boarder incident locations and areas given in Table 3.

[5] The grid is known as Marsden Squares which was named after a former Secretary to the Admiralty who introduced the system in 1831 and which is still used today.

Table 2: Classification of casualty types

Casualty type	Abbrev. in plots	Description
1. collision and contact	CC	Collision is between two ships while contact is between a ship and another object. The vessel in general remains mobile.
2. fire/explosion	FE	Fire and explosion anywhere on the vessel
3. hull related failures	HRF	Hull related items such as maintenance items (cracks, holes, fractures, hatch cover problems, cargo equipment failure, lifeboat gear failure, anchor and mooring ropes problems)
4. machinery related failures	MRF	Machinery related items including engine breakdown, black outs and other electrical failures, steering gear failure and propulsion failure
5. wrecked/stranded/grounded	WSG	a large portion of the ships in this category are stranded or grounded. Nevertheless, for the purpose of the analysis, this category is to be interpreted primarily for stranded and grounded vessels
6. flooding/foundering/capsizing	FFC	in this category, the vessel is partly covered with water or totally submerged.
7. miscellaneous	Misc	miscellaneous: any other type which could not be classified

Note: Abbreviation used in the plots are given in brackets if different from the abbreviation used

Table 3: Incident regions and location details

Locations	Regions (Abbreviations used in the plots are given in brackets)
1. Arabian Gulf, Indian Ocean, East Africa 2. Australasia, South Pacific, South Pole 3. Baltic Sea, Kiel Kanal 4. Canadian and Russian Arctic and Alaska 5. British Isles, North Sea, English Channel, Bay of Biscay 6. Great Lakes 7. Iceland 8. Japan, Korea and North China 9. Mediterranean East & Black Sea 10. Mediterranean West 11. NA East Coast and North Atlantic 12. NA West Coast and North Pacific 13. SA East Coast and South Atlantic 14. SA West Coast and Panama Canal 15. South China, Indo China, Indonesia and Philippines 16. Newfoundland 17. Suez Canal, Red Sea 18. West African Coast 19. West Indies and Gulf of Mexico	1. North Atlantic (NA) 2. East Africa, Indian Ocean (EA&IO) 3. Japan, Korea, South China Sea (JKSCh) 4. South Atlantic, West Africa (SA & WA) 5. North Pacific (NP) 6. South Pacific, Antarctica (SP&A) 7. Mediterranean., Red Sea and Black Sea (Med&Red&Black) 8. Caribbean, Gulf of Mexico, Panama Canal (Carib&Gulf&Pan)

The last data groups which are explained in this section are groups for the loss of life and pollution quantity given in Table 4 where we also provide the labels used in the plots. Quantity is split into four groups with an additional category identifying unknown status. We also have some information on pollution type but unfortunately the data quality and quantity is rather poor making it impossible to visualize individual pollution type categories. For the same reason, it is not easy to identify pollution quantity. To optimally process the available data they were manually reclassified for quantity and type, and the various units were translated into tonnes of pollution for each observation with pollution quantity information. Finally, for loss of life, five groups were created. However, in order to zoom in on the group in which loss of life was observed, the category 'none' is not used in the plots.

Table 4: Pollution and loss of lives groups

Pollution Quantity		Loss of Life	
groups	**labels in plot**	**groups**	**labels in plot**
unknown	n/a	none	n/a
none	none	1 to 5	low
below 100 tonnes	low	6 to 15	medium
100 – 1000 tonnes	medium	16 to 30	high
Below 100 tonnes	high	above 30	very high

Note: n/a = not applicable since we exclude observations with unknown status from the plots

4. Visualization of Risk Profiles

The risk profiles are divided into several types of risk profiles depending on the type of relationship we are interested to visualize. We divide the profiles into general risk profiles, risk profiles involving loss of life and pollution and profiles involving incident locations (regions). In order to demonstrate changes of the profiles over time, we divide the total time periods into either four or three time periods. The four time periods; 1: 1977-1986, 2: 1987-1997, 3: 1998-2002 and 4: 2003-2008, are used for the general ship risk profiles and location risk profiles excluding loss of life and pollution. The three time periods; 1: 1977-1987, 2: 1988-1997, 3: 1998-2008, are used for the plots involving loss of life and pollution. The reason for splitting the period into three rather than four periods is the lower data quality and quantity for the loss of life and pollution variables.

For the four time periods, periods 3 and 4 are shorter in order to account for important changes in the legislative framework such as the introduction of the *International Safety Management Code* (ISM Code) which came into force in 1998 (passenger vessels, tankers and dry bulk carriers) and 2003 (all other ship types) respectively. We also link the plots to other developments in the international or regional legislative framework as well industry activities such as vetting inspections. Vetting inspections are performed by industry interests and are stringent safety inspections for oil tanker and chemical tankers and more recently for dry bulk carriers. Vetting inspections started in 1993/1994 as a reaction to the 1989 *Exxon Valdez* incident which also triggered regional legislation in the United States of America. Vetting inspections on dry bulk carriers is a relative new concept and started in 2002.

In shipping, it is very common that changes to legislation occur after major incidents such as a series of oil tanker disasters in the 1970's and, more recently, the 1999 *Erika* and the 2002 *Prestige* incidents. Furthermore, some changes happen relatively fast due to political pressure and media exposure. The same applies to passenger vessel incidents such as the 1987 *Herald of Free Enterprise* or the 1994 *Estonia* incident. For other segments such as dry bulk, reactions to incidents can be slower since there is less pressure. As an example, changes to dry bulk carrier safety measured influenced by the 1980 *Derbyshire* incident was adopted in 1997 and 2002 respectively.

In interpreting the plots we also link the results to the development of port state control regimes since it reflects enforcement of the international legislative framework. Important to note are the adoption dates of the various Memoranda of Understanding (MoU) on port state control across regions which started in the 1980's up to 2004. Currently in force are 9 such regimes and the United States Coast Guard (USCG) which shifted its emphasis on foreign vessel inspections in 1994. The regimes are as follows [14] in chronological order of their creation:

- 1982: Europe and North Atlantic (Paris MoU)
- 1992: Latin America (Acuerdo de Viña del Mar)
- 1993: Asia and the Pacific (Tokyo MoU)
- 1994: United States Coast Guard (USSC)
- 1996: Caribbean (Caribbean MoU)
- 1997: Mediterranean (Mediterranean MoU)
- 1998: Indian Ocean (Indian Ocean MoU)
- 1999: West and Central Africa (Abuja MoU)
- 2000: Black Sea (Black Sea MoU)
- 2004: Arab States of the Gulf (Riyadh MoU)

4.1. General ship risk profiles

We use JCA to analyze, for each period, the interaction within and between the general ship risk profile variables and the casualty variable. For these profiles we first use the standard ship particulars which influence safety quality of a vessel such as ship type, age, flag and the classification society along with the casualty types identified earlier. We are interested to see how the variables relate to each other and whether the profiles changed over the four time periods. The second half of this section also includes two plots where we are interested in visualizing the relationship between ship particulars, loss of life and pollution including the changes over the three time periods.

The results are summarized in Figure 1. Each subplot of Figure 1 visualizes the individual risk profiles for each period. The fit for all four analyses was quite high; 82%, 82%, 76%, and 78% explained inertia respectively. In Figure 1, we see that the plots appear quite similar over the time periods. Younger ships are found on the left hand side, classified by IACS class and more likely to be flagged by white or grey listed flags. Non-IACS and undefined class and black listed or undefined flags are associated with older vessels and are found on the right hand side of the plot. One cannot detect a significant shift over time with respect to these associations. (Note that, similar to factor analysis, rotation is an option in JCA. However, the presented solutions were not rotated, as the orientation of the four plots is already quite similar allowing easy comparison).

For the risk profiles, we find our expectations for general cargo ships partly confirmed. These are that older ships are more likely to have casualties with more serious consequences such as wrecked, stranded, grounded (WSG), flooded, foundered or capsized (FFC) than younger ships of any other ship type. In addition, we can confirm that general cargo vessels are also expected to be associated with a poorer safety record (black listed flag and Non-IACS classification societies). Dry bulk vessels are found to be more prone to hull related failures (HRF) in period 3 and 4 compared to period 1 and 2 where tankers appear to be closer to this type of casualty. Comparing the individual plots, we see that tankers and container vessels are found on the left with younger ships and associated with white listed flags and mainly IACS classification societies. In the earliest period, dry bulk carriers can also be found with this group but later on shift more to the right and towards older age groups.

With respect to the casualty types, one can observe some changes with respect to ship type and type of casualty. Hull and machinery related failures (HRF, MRF) and contact and collisions (CC) are closest associated to tankers, container vessels and dry bulk carriers in period 1. The association changes slightly in the other periods where especially HRF move towards general cargo ships and away from tankers and dry bulk carriers. The shift of HRF for tankers and dry bulk carriers could be explained due to the entry into force of the Oil Pollution Act (OPA 90) of the United States of America during period 3 (1998-2002) and following the 1993 *Exxon Valdez* incident. In parallel to OPA 90, IMO amended MARPOL[6] in 1992 and 2003 [15] accelerating the phasing out of single hull tankers and implementing the condition assessment scheme (CAS). By 2010, all single hull tankers should be phased out. CAS applies to certain oil tankers and requires mandatory additional verification of structural conditions of tankers which is assessed via the Enhance Survey Programme as part of the mandatory surveys conducted on tankers and bulk carriers.

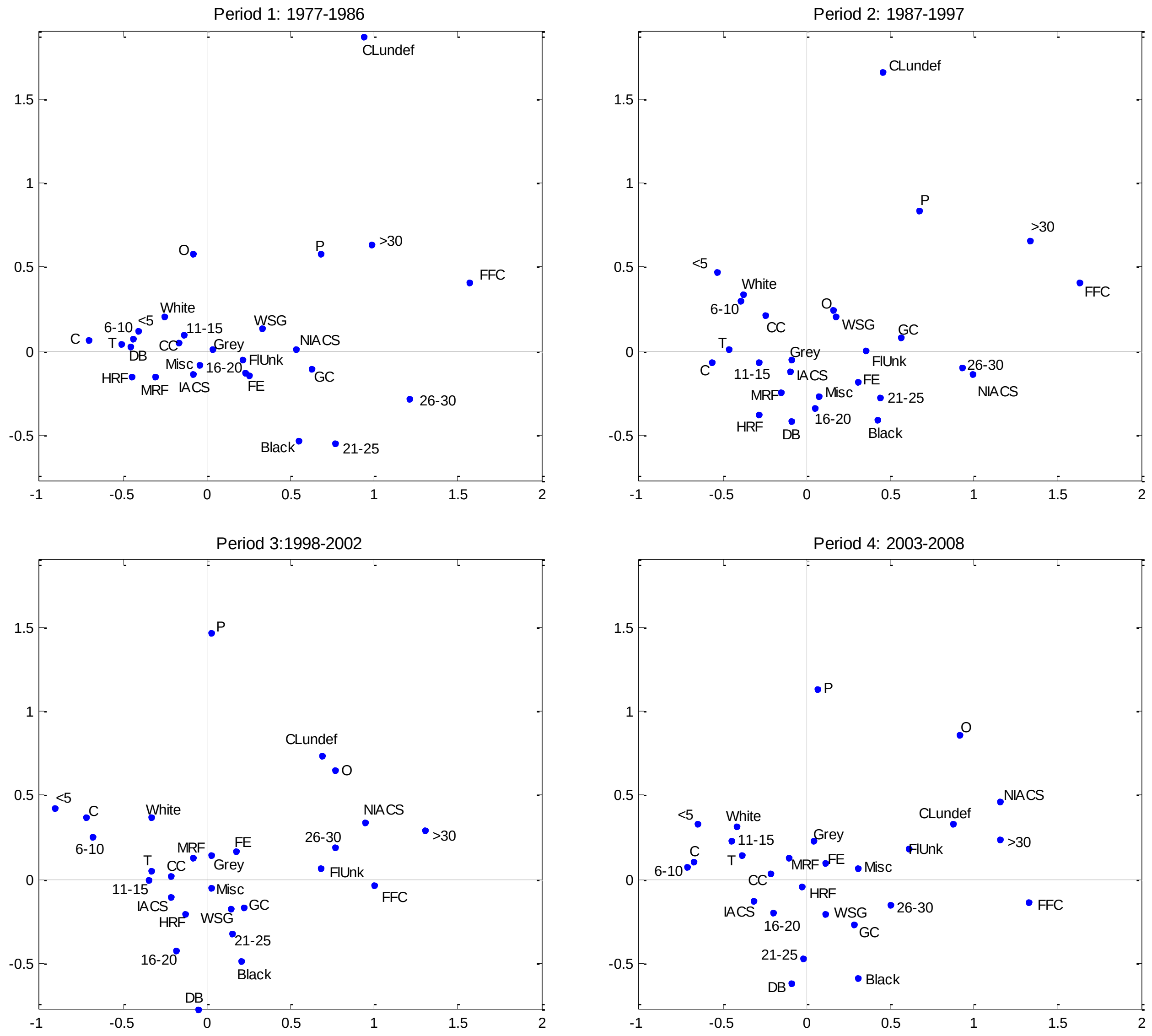

Figure 1: Joint correspondence analysis plots for basic risk profile data. For a description of the labels see Tables 1 and 2.

[6] The International Convention for the Prevention of Pollution from Ships (MARPOL 73/78)

In addition to the legislative measures, industry vetting inspections started in the 1990's for oil tankers and chemical tankers which helped improving standards. For dry bulk carriers, industry inspections started in the early 2000's but dry bulk carriers also adhere to an Enhanced Survey Programme. In addition and following the 1997 *Derbyshire* incident, IMO amended SOLAS[7] [15] and introduced additional safety measures which came into force in 1999 and 2004.

Passenger vessels in the most recent period are in the direction of white and grey listed flags which indicates better performance. In earlier periods (1977-1997), the ship type is associated with older age and located in the direction of flooding, foundering and capsizing (FFC). It is interesting to note that the 1987 *Herald of Free Enterprise* incident at the coast of Belgium triggered the development of the ISM Code which entered into force in July 1998 for passenger vessels, tankers and bulk carriers and in July 2002 for all other ship types. Furthermore, the 1995 *Estonia* incident where 852 lives were lost in the Baltic Sea influenced amendments to SOLAS [15] with respect to stability and lifesaving appliances.

The results for the most recent period in Figure 1 indicate that older general cargo ships registered with black listed flags are more risk prone towards flooding, foundering and capsizing (FFC) and are more likely to be wrecked, stranded or grounded (WSG) or encounter hull related failures (HRF). Container vessels and tankers tend to be relatively young and are associated with white listed flags and IACS class but are associated with collisions and contacts (CC) and machinery related failures (MRF).

Figure 1 presents a nice visualization of all interactions between the variables considered in our analyses. The similarity of the four subplots indicates that change over time was somehow limited. To focus in on the changes over time, we perform CA on a concatenated contingency table. For each time period, we record for each casualty type, the distribution over the categories of the ship particulars. We then collect these data in a so-called concatenated contingency table by stacking the resulting tables. Thus, in the resulting table we have four rows (one for each period) for each casualty type. The columns of the table correspond to the categories for the ship particulars of Table 1. Applying CA to this table yields Figure 2 with 78.9% of explained inertia.

In Figure 2, the points corresponding to the different periods are numbered (eg FE1, FE2, FE3, FE4 indicates fire and explosion for period 1 to period 4 respectively). In this analysis we use the groups for flags and classification societies as supplemental variables in order to suppress their interaction with age and ship type. Figure 2 zooms in on the changes over time. It exhibits a general shift of all casualty types towards older vessels. This shift can be interpreted as an overall performance increase of the fleet supplemented by the phase out of single hull tankers, the additional safety measures for dry bulk carriers and the implementation of the ISM code applying to all ship types. Flooding, floundering and capsizing (FFC) can be found on the right hand upper side for all periods. This type of casualty is associated with older ships in all periods.

For the other casualty types, there appears to be a general pattern in which the point corresponding to period 1 is located on the left hand side of the plot whereas the point corresponding to period 4 is much farther to the right. In particular, for most casualty types, a large gap exists between the casualty point corresponding to periods 2 and 3. This

[7] The International Convention for the Safety of Life at Sea (SOLAS 1974)

means that, for example, in period 3, hull related failures (HRF3) occur relatively more frequently on ships older than 21 years than they did in the previous periods when hull related failures also occurred on younger ships. In fact, this holds for all casualty types indicating that in the two recent periods casualties of all types appear to occur less and less on younger ships.

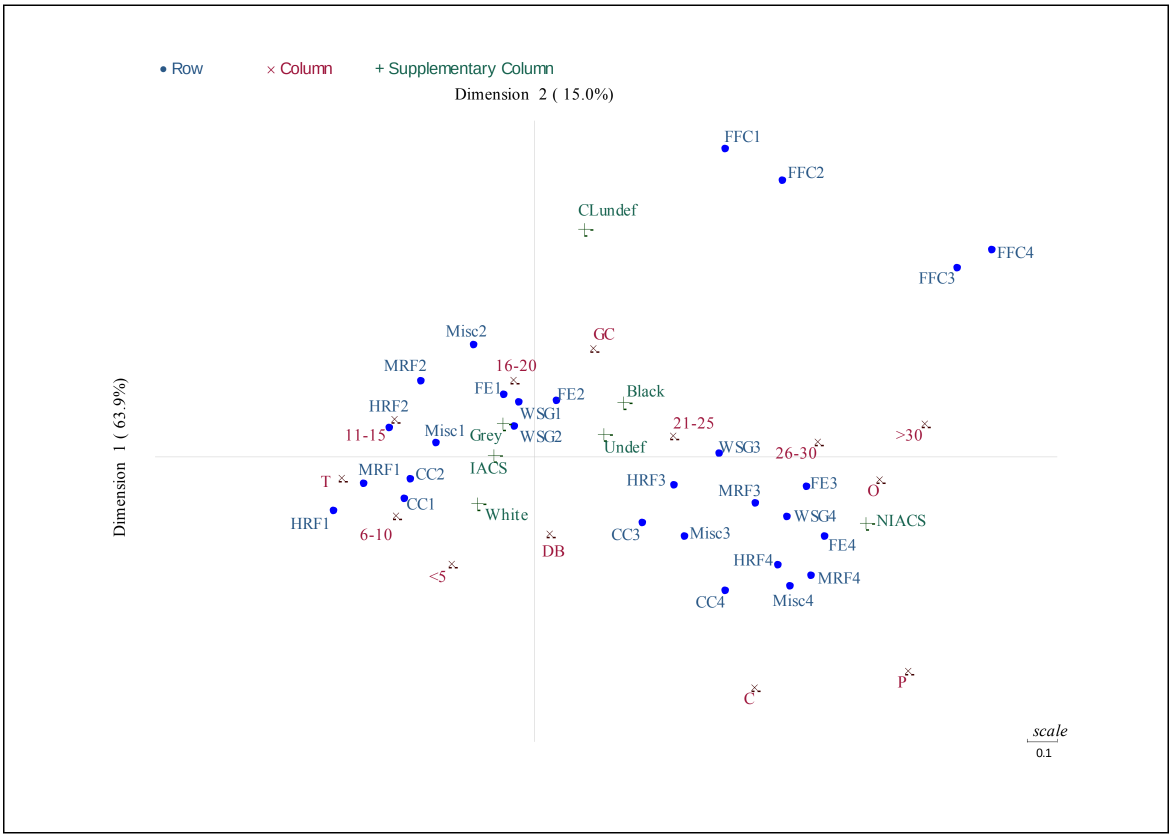

Figure 2: Symmetric CA biplot of ship risk profile changes over all periods (1977-2008). For a description of the labels see Tables 1 and 2. Casualty type labels are numbered according to the corresponding periods: 1 for1977-1986, 2 for 1987-1997, 3 for 1998-2002 and 4 for 2003-2008.

In summary, one can conclude from Figure 2 that the overall performance of the fleet improved over time. Casualties shifted towards older ships. For the flooding, foundering and capsizing (FFC) category the improvement is weakest as this type of casualty is associated primarily with older ships in all periods. The shift in overall performance can be explained with the implementation of the ISM Code, OPA 90, the MARPOL amendments introducing the phase out of single hull tankers and additional safety measures based on the SOLAS convention. This is further complemented by the increase of port state control inspections over time with more regimes starting to operate gradually starting 1985 up to 2004. Further more, tankers, dry bulk carriers and general cargo vessels improved more compared to passenger vessels and container vessels which could be explained due to the impact of the industry vetting inspections for tankers and dry bulk carriers.

4.2. Risk profiles with locations

In addition to considering risk profiles and casualty types, we visualize the relationship of ship particulars and locations (regions) over the four time periods. In interpreting the results for locations, we also refer to the results of the general ship risk profiles where appropriate. Figure 3 uses the same method used for Figure 2 and zooms in on the changes over time. For this plot, we used the eight regions given in Table 3. The resulting CA solution provides a good fit with 80.4% inertia explained in two dimensions.

One can observe more changes with respect to the casualty types and location than with the ship risk profiles over time. The only exception is casualty type flooding, foundering and capsizing (FFC) which can be found on the lower right hand side of the plot and in the same direction with the Caribbean and the Mexican Gulf (Carib&Gulf&Pan), especially for FFC3 and FFC4. The Caribbean is an interesting region. Many small cargo ships operate in this region of which most are outside the international legislative framework. SOLAS applies to all ships of 500gt and above. In 1996, the Caribbean Memorandum of Understanding came into existence and adopted the Code of Safety for Caribbean Cargo Ships (CCSS Code) [16]. The Code should address the special situation in the region and set acceptable standards for vessels below the 500 gt. The results indicate that the region could benefit from increased application and enforcement of the code.

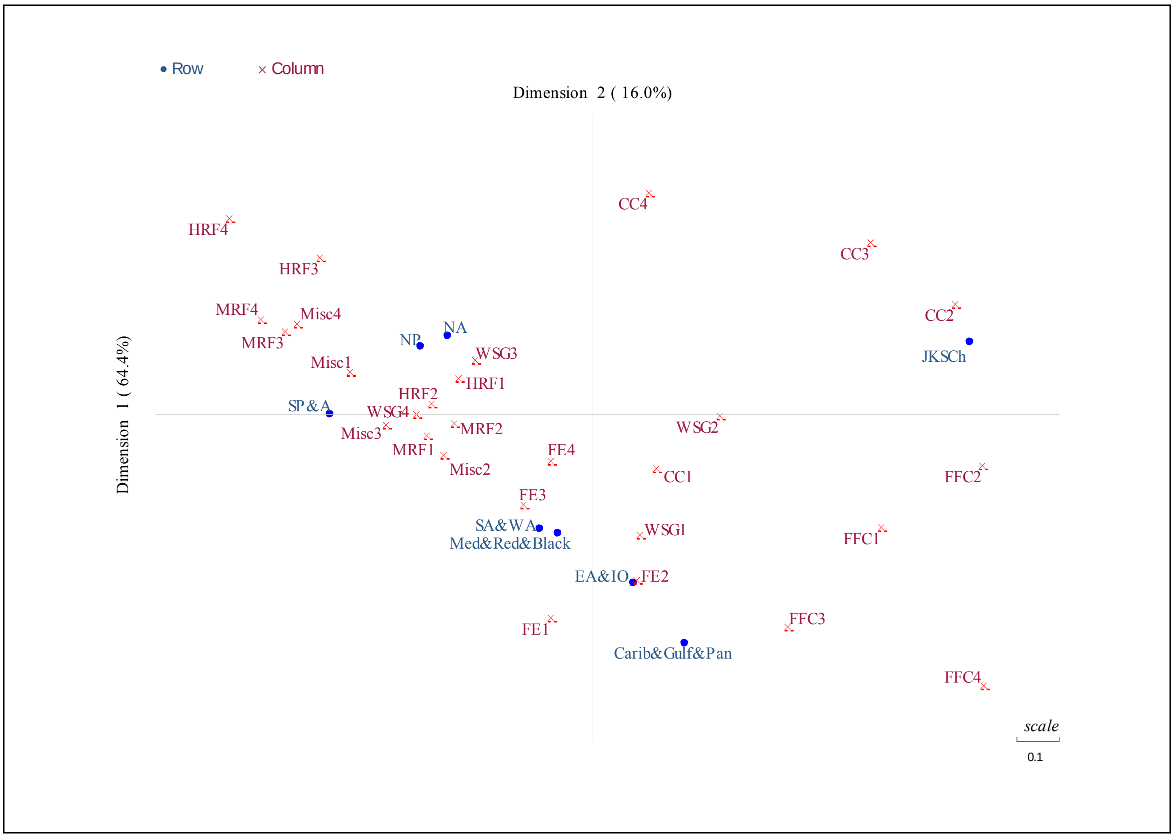

Figure 3: Symmetric CA biplot of location risk profile changes over all periods (1977-2008). For a description of the labels see Tables 2 and 3. Casualty type labels are numbered according to the corresponding periods: 1 for1977-1986, 2 for 1987-1997, 3 for 1998-2002 and 4 for 2003-2008

For the older periods, we can also see flooding, foundering and capsizing (FFC) associated with the Japan, Korean and South China Sea (JKSCh). This region is similar to the Caribbean and is also characterized by inter-regional trade on smaller ships of which some might be outside the legislative framework. The Tokyo MoU was introduced in 1993 which is in the middle of period 2 (1987-1997) when the casualty types FFC2, CC2 and WSG2 is closest to this area and shifted away in more recent periods. It is also interesting to note that CC3 is still closer than the other casualty types and this could be due to the increase in the container trade due to China. From the ship risk profiles, we also see that this particular casualty type is associated with container vessels.

Interesting to see is the little change of casualty type fire and explosion (FE) over all periods. FE1, FE2, CC1 along with WSG1 are found in the vicinity of East Africa and the Indian Ocean region (EA&IO). The region is influenced by the in transit container traffic from Europe to Asia and the dry bulk market from Europe, Africa and South America to China. It is also the prime area for oil exports to all over the world. The Indian Ocean MoU started operating in 1998 which is in the beginning of period 3 (1998-2002). The region is also covered by the Riyadh MoU which is specific for the Arab states of the gulf area but only started in 2004. The results of Figure 3 suggest that the safety profile of the region improved over time which is most likely a combination of the legislative framework for oil tankers and the increased enforcement within the region.

The Mediterranean, Red Sea and Black Sea area (Med&Red&Black) and the South Atlantic and West Africa (SA&WA) regions are close to each other in the plot indicating a similar distribution over the casualty types and periods. For the most recent periods, these regions are associated with incidents involving fire and explosion (FE3) and for earlier periods with WSG1. Both areas are covered by port state control MoU's but the West African is not fully operational while the Mediterranean and Black Sea MoU have been in force since 1997 and 2000. West Africa is an increasing oil export and offshore area and this could explain its association with FE3 and FE4. For the South American Region, we have the Viña del Mar Agreement since 1992. Especially the east coast of South America is important for the dry bulk trade and one would expect to see an association with hull related failures which is not the case.

The most recent periods for HRF, MRF and WSG are found on the left hand part of the plot and are in the same direction as the South Pacific and Antarctica (SP&A), North Pacific (NP) and North Atlantic (NA). The North Pacific constitutes the trade flow out of North and Central America while the North Atlantic covers the area between the US and Europe. Theses areas are covered by the Paris MoU which started operation in 1983 and the Tokyo MoU operating since 1993. The North Atlantic is known for its rough weather conditions especially in the winter months which could explain its closeness to WSG3 in the period 1998 to 2002. It is also associated with HRF in period 1 and 2 than for the most recent periods. In this regard, it is interesting to note that due to European Union legislation, the Paris MoU implemented the concept of expanded inspections for bulk carriers, tankers and passenger vessels of 15 years and higher. During expanded inspections, inspectors also inspect tanks and pay more attention to structural conditions of the ship which might explain the shift and improvement in HRF. Another explanation might simply be the phase out of the single hull tankers.

The result for the South Pacific region with respect to MRF3, HRF2(3) and WSG4 is more difficult to interpret due to the large area that is included in this area. It contains Australasia, Antarctica and the West Coast of South America. Most relevant for MRF might be the increase in trade to and from South America. UNCTAD [17] reports in its 2008 Maritime Transport Review that capacity for container shipments more than doubles on the routes to and from South America between 2000 and 2007. The same report also indicates that the average fleet age of the Europe to West Coast of South America trade increased by 2 years meaning that older ships operate in this segment. For other trade segments, port traffic increased yearly in Chile by 23.2%, in Peru by 9.2% and in Colombia by 14.4% for the period 2000 to 2004. The closeness to WSG4 could be explained by the severe weather conditions around South America for ships that cannot transit the Panama Canal for the European trade or the general cargo trade for inter-regional traffic. For HRF3 and HRF2, Australia might come into the picture since it is very important in the dry bulk trade. Vetting inspections on dry bulk carriers started in 2001 (at the end of period 3).

It is worth noting that casualty type wrecked stranded and grounded (WSG) changes considerably across the regions depending on the time period. It is closer to East Africa and the Indian Ocean in earlier periods and then shifts towards Korean, Japan and South China Sea. In period 3, it is close to the North Atlantic and North Pacific region while in the last period is it closest to the South Pacific region. Comparing this result with the ship risk profiles, WSG in the latest period is associated with older general cargo ships registered by black listed flags. We can conclude that this refers primarily to the South American trade and not so much Australia since Australia is dominated by dry bulk carriers.

In summary, the risk profiles involving location show more variation and changes over the time periods with respect to the casualty types then the general ship risk profiles. Some regions improved their safety profile such as the Indian Ocean Region and the area including Japan, Korea and the South China Sea. Regions with more casualties in the recent periods, especially for HRF, MRF and WSG are the South and North American East coast and the North Atlantic region. The results further demonstrate that perhaps more emphasis needs to be placed on regions with inter-regional trade characterized by older general cargo ships. This case can especially be seen in the Caribbean region and the Gulf of Mexico where the international legislative framework does not cover smaller ships below the 500gt threshold. Some of the variations could also be caused by changes in trade flows over time where some areas are more affected than others.

4.3. Risk profiles with loss of life

In this section we explore the relationship between ship particulars, incident locations and loss of life. Due to the relative scarcity of data, splitting the data into four periods is not feasible. Instead, three time periods will be considered. Appendix 1 provides a table summarizing some useful statistics. It is worth noting that 96% of all incidents do not involve loss of life for the total time period (1978 to 2008). From Appendix 1, we can observe that in absolute terms, most lives were lost in the South China Sea including Indonesia and the Philippines and that this trend continues for the last five years. The area is known for ferry incidents operating between islands where some ferries are not regulated by the international legislative framework. One such ferry accident was the 1987 *Dona Pax* incident in the Philippines where 4000 lives were lost. Comparing the last five years, one cannot observe a decreasing tendency. The 2006 figure is high due to the *Al Salam Boccachio* ferry incident in the Red Sea.

In Figure 4 we apply CA to the distributions over categories for loss of life, casualty types, ship types, age and flag groups. We use age groups as supplemental points. The categories for loss of life are split into the three time periods and are as follows: low (1-5 lives), medium (6-15 lives), high (16-30 lives) and very high (above 30 lives). Similar to the general risk profiles, the period are indicated with numbers (e.g. very high 3). Figure 4 visualizes the relationships for ships that had loss of live. Casualties without loss of life were excluded from the analysis to focus on the group yielding casualties. On the right hand side of the plot, one can find younger ships with lower loss of life followed by the medium group (6-15) in the middle of the plot and the high and very high loss of life groups on the left hand side. All loss of life categories move towards older ships in period 3.

Casualty types with relatively many instances of loss of life between 1-5 in period 3, are contact and collision (CC), hull and machinery related failures (HRF, MRF). For the medium loss of life category, period 3 is closest to flooding, floundering and capsizing (FFC) and wrecked, stranded, grounded (WSG). For the high loss of life category, FFC is also closets. For the association of loss of life with FFC and WSG, it is interesting to note that the Sub-Committee on Ship Design and Equipment at IMO [18] recently developed draft guidelines to ensure that release mechanisms of lifeboats are replaced with better designs in order to reduce incidents with lifeboats. This was complemented by recommendations on the testing of life savings appliances concerning test procedures for lifeboat hooks. For both incident types, the proper functioning of lifeboats and their release mechanism is important for survival since it evacuation of the vessel is more likely than with other casualty types. One of the problem areas which have been identified are operations of lifeboats and their release mechanism. The results in Figure 4 confirm this finding.

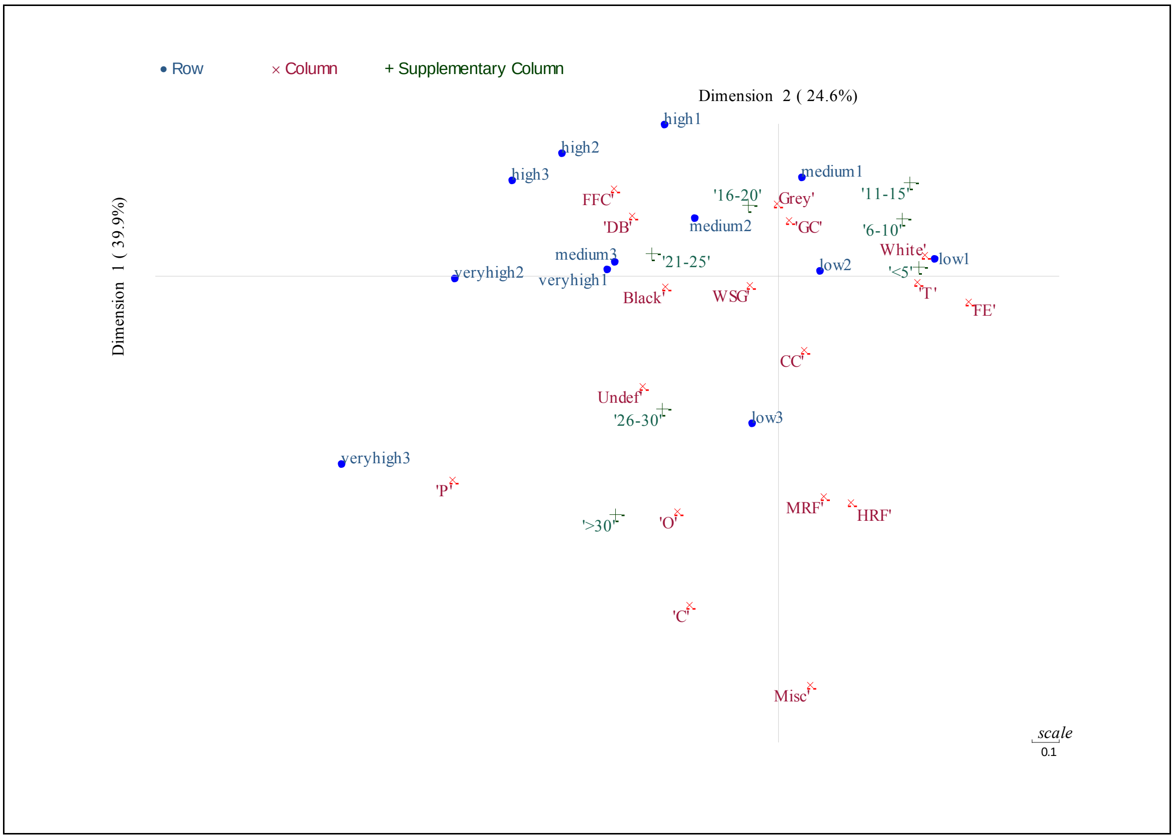

Figure 4: Symmetric CA biplot of ship risk profile with loss of life and changes over all periods (1977-2008). For a description of the labels see Tables 1, 2 and 4. Time periods are 1 for 1977-1987, 2 for 1988-1997, 3 for 1998-2008.

The very high loss of life category appears to be most closely associated with passenger vessels. In particular, in period 3, very high loss of live appears to occur relatively more often with passenger vessels. From the plot, one can also observe that dry bulk vessels (DB) are associated with 6-16 lives lost while general cargo vessels (GC) are associated with the lower and medium category in period 2. Tankers are closest to the younger vessel group with low loss of life and casualty type fire and explosion. With respect to flag groups, white listed flags are associates with lower loss of life compared to grey and black listed flags. The undefined flag group is closest to the high loss life category in period 3.

In summary we can conclude that most incidents do not involve loss of life and based on descriptive statistics, we cannot detect a downward trend over the last five years. In terms of absolute figures, high risk prone areas are the North and South China Sea, Japan and South Korea, the Mediterranean, Red and Black Sea and the Arabian Gulf. Casualty types flooding, foundering and capsizing are more likely to lead to loss of life (6-15 and 16-30) than other casualty types. Lower loss of life (1-5) is more likely to be found with collision, contact, hull and machinery related failures. For all periods and loss of life categories, a shift can be observed towards older vessels. Passenger ships are more likely to have increased loss of lives than other ship types with incidents that involve loss of life followed by dry bulk carriers, general cargo ships and tankers. With respect to flag groups, white listed flags are associates with lower loss of life compared to grey and black listed flags.

4.4. Risk profiles with pollution

The final area of analysis for this article will visualize relationships with respect to pollution. As explained earlier, data population in the shipping industry is very poor on the quantity and type of pollution. For about 90% of all incidents in the dataset, we do not know if pollution was involved. Even oil pollution in our dataset which is relatively well populated based on data from Lloyd's Register Fairplay is lower than for instance totals reported by the International Tanker Owner Pollution Federation (ITOPF) for the same time period. This could be due to the fact that many small pollution quantities go unreported in the media. From the observations that do have pollution, about 60% do not involve pollution and the remaining incidents do involve some type of pollution.

Appendix 2 provides some descriptive statistics of pollution quantities and types with respect to locations for the whole time period while Figure 5 visualizes the figures presented in Appendix 2 in a plot. We can observe from Appendix 2 that most of our data is from heavy and crude oil pollution and very little from the other pollution types. Appendix 2 further suggests that in absolute terms most pollution occurred in the area of the British Isles, the North Sea, the English Channel and the Bay of Biscay where many tanker accidents occurred. Another risk prone area is the Arabian Gulf, the West Indies and the Gulf of Mexico and the West African Coast. The Arabian Gulf is heavily frequented by tankers. The Marine Emergency Mutual Aid Center (MEMAC) [19] reports 47,000 ship entries into the area for 2007. Second, the spills peaked in the 1991 Gulf war with large amount of oil coming from other sources than tankers such as oil fields and refineries [19]. Our data reflects the ship portion where some tankers also became the victims of military actions. Despite the influence of the war, the region has shown to be risk prone and MEMAC in conjunction with the Regional Organization for the Protection of the Marine Environment (ROPME) developed an action plan to raise awareness and to increase training in managing oil spills.

Figure 6 visualizes the relationship of pollution quantity with casualty types, age of the vessel and flag groups. In this plot, we do not include ship type since most pollution is oil and is therefore related to tankers. Pollution quantity is split into low (below 100 tones), medium (100 to 1000 tones) and high (above 1000 tones). We also include observations with no pollution ('none') in the plot. The plot shows the periods associated with no pollution on the left hand side associated with casualty type fire and explosion (FE), and machinery related failures (MRF).

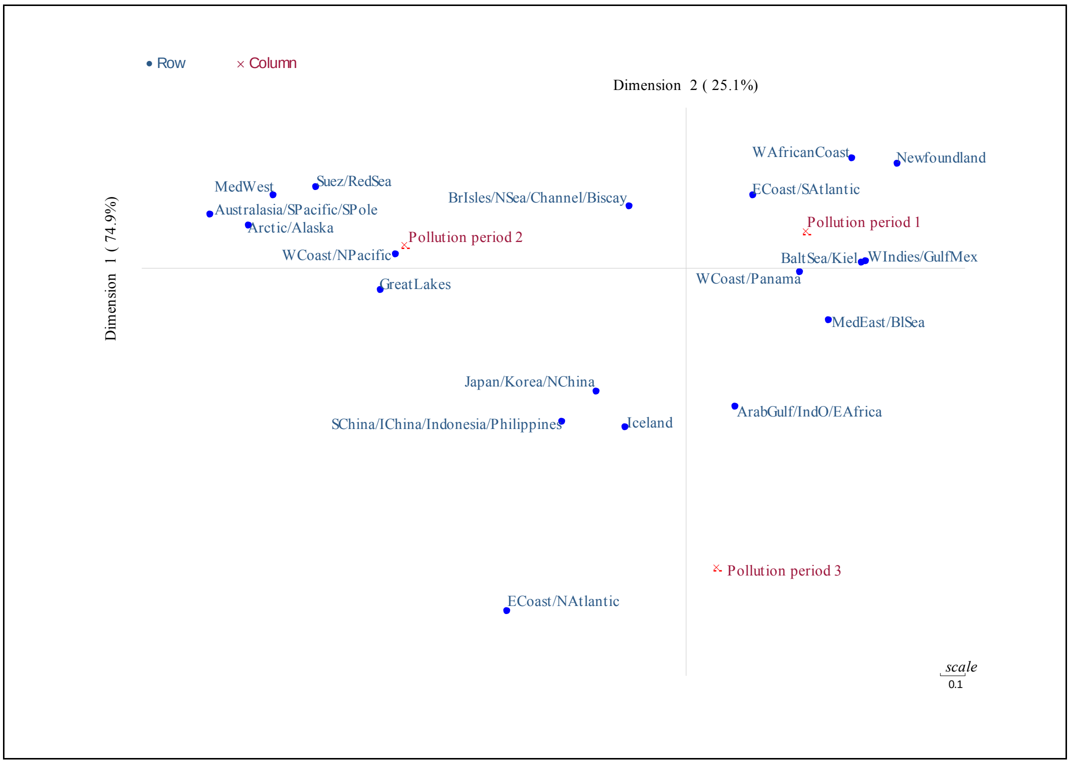

Figure 5: Symmetric CA plot of ship risk profile with loss of life and changes over periods. Time periods are Pollution period 1 (1977-1987), Pollution period 2 (1988-1997) and Pollution period 3 (1998-2008)

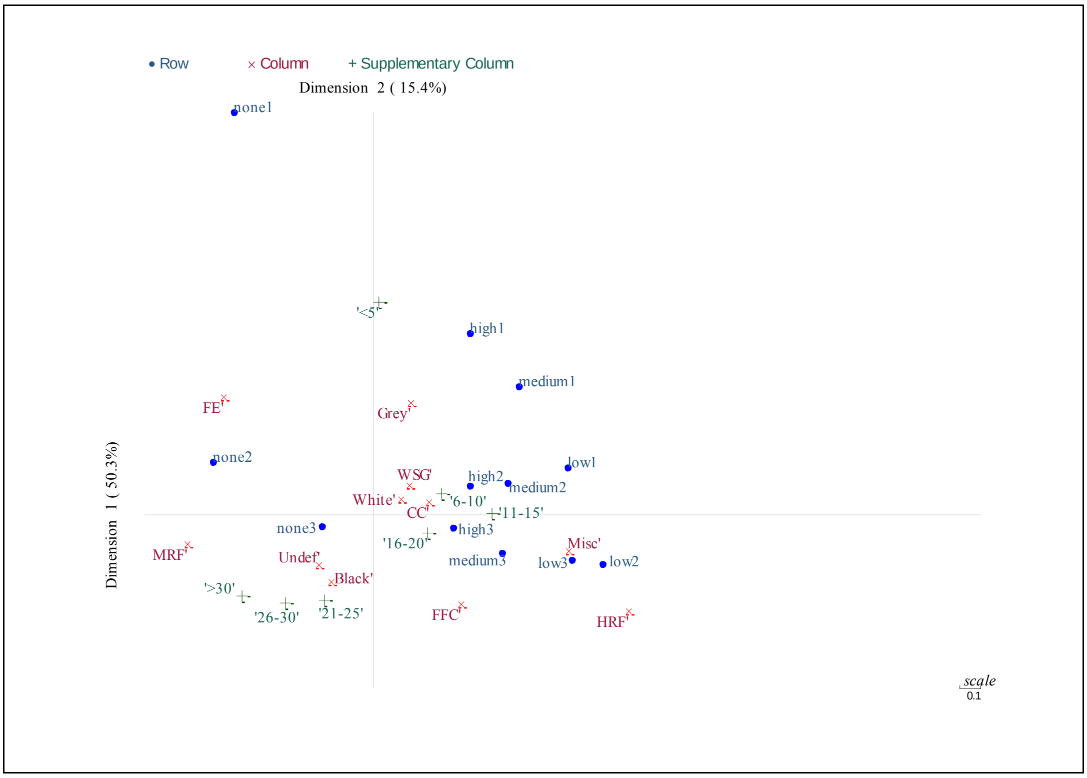

Figure 6: Symmetric CA biplot of ship risk profile with loss of life and changes over all periods (1977-2008). For a description of the labels see Tables 1, 2 and 4. Time periods are 1 for 1977-1987, 2 for 1988-1997, 3 for 1998-2008.

Interesting to note is that older ships are also located on the left hand bottom part of the plot in the same direction as black listed or undefined flags. The high pollution category is associated with younger and medium aged vessels (6-10 years and 16-20 years) and with casualty types collision, contact (CC), wrecked, stranded, grounded (WSG) and flooding, foundering and capsizing (FFC). This may seem counter-intuitive, however, recall from Figures 1 and 2 that tankers are typically younger ships. The flag categories for white and grey listed flags are also associated with this group. The low pollution category is located on the right hand side of the plot and associated with hull related failures (HRF). At first instance this might be an unexpected associations but it could reflect the change of the tanker fleet with the phase out of the single hull tankers and the increased used of double hull tankers due to legislative measures.

In summary, we can conclude that in absolute terms most pollution occurred in the area of the British Isles, the North Sea, the English Channel and the Bay of Biscay. Another risk prone area is the Arabian Gulf, the West Indies and the Gulf of Mexico and the West African Coast. Data on pollution quantity and types is poorly populated, especially for pollution types other than oil. The plots suggest that most pollution is not necessarily found on older ships and are not related to hull related failures which show the effect of the phase out of the single hull tankers and the move of the tanker fleet towards younger vessels. High pollution quantities are more likely to be found due to collision and the vessel being wrecked, stranded and grounded than with other casualty types.

5. Conclusions

This article uses correspondence analyses to visualize ship risk profiles and their changes over the time frame of 1977 to 2008. CA and JCA were used to visualize various relationships between ship particulars, casualty types, incident locations, loss of life and pollution. The analysis is based on a unique dataset which combines incident data and ship particular data from various sources. The profiles can help various stakeholders such as regulators and insurance companies to improve the understanding of the relationship of ship particulars, casualty types and locations. Visualization of the changes of risk profiles over time can also assist in visualizing the effect of the legislative framework and identify areas for improvement.

The results indicate that safety performance of the fleet improved over time. Casualties in general shifted towards older ships. Furthermore, tankers, dry bulk carriers and general cargo vessels improved more over time compared to passenger vessels and container vessels which could be explained due to the impact of the industry vetting inspections for tankers and dry bulk carriers. The improvement of the fleet can be explained with the implementation of the ISM Code, OPA 90, the MARPOL amendments introducing the phase out of single hull tankers and additional safety measures based on the SOLAS convention. This is further complemented by the increase of port state control inspections over time with more regimes coming into action from 1985 onwards up to 2004.

The results for the most recent period indicate that older general cargo ships registered with black listed flags still remain risk prone towards flooding, foundering and capsizing and are more likely to be wrecked, stranded or grounded or encounter hull related failures. Container vessels and tankers tend to be relatively young and are associated with white listed flags and IACS class but are associated with collisions and contacts and machinery related failures.

The risk profiles with respect to locations indicate more variety over the time periods with respect to the casualty types. Some regions improved their safety profile such as the Indian Ocean Region and the area including Japan, Korea and the South China Sea. Regions with more casualties in the recent periods, especially for HRF, MRF and WSG are the South and North American East coast and the North Atlantic region. The results further demonstrate that more emphasis needs to be placed on regions with inter-regional trade characterized by older general cargo ships. This case can especially be seen in the Caribbean region and the Gulf of Mexico where the international legislative framework does not cover smaller ships below the 500gt threshold. Some of the variations could also be caused by changes in trade flows over time where some areas are more affected than others.

Most incidents do not involve loss of life. After a dramatic drop after 1987, the total number of lifes lost appears to be stable. In terms of absolute figures, high risk prone areas are the North and South China Sea, Japan and South Korea, the Mediterranean, Red and Black Sea and the Arabian Gulf. Casualty types which are more likely to lead to higher loss of life are flooding, foundering and capsizing on vessels which are flagged with black listed flags or undefined. For all periods and loss of life categories, a shift can be observed towards older vessels. Passenger ships are more likely to have higher counts of loss of lives than other ship types.

Data on pollution quantity and types is poorly populated, especially for pollution types other than oil. In absolute terms, most oil pollution occurred in the area of the British Isles, the North Sea, the English Channel and the Bay of Biscay. The plots suggest that most pollution is not necessarily found on older ships and are not related to hull related failures which show the effect of the phase out of the single hull tankers and the move of the tanker fleet towards younger vessels. High pollution quantities are more likely to be found due to collision and the vessel being wrecked, stranded and grounded than with other casualty types.

Future research could concentrate on extending the analysis and also include the Document of Compliance Company (DoC) as one of the variables or beneficial ownership of the ship risk profiles. The DoC company is the company responsible for the safety management required by the ISM Code. Furthermore, data providers should be encouraged to improve data population on quantity and type of pollution in the future since very little data is available.

Acknowledgments
We would like to thank Lloyd's Register Fairplay in providing casualty data used in this analysis. For the JCA analyses, a Matlab program written by the second author was used. This program is freely available upon request from the second author. For the CA plots, the Matlab program *CAR* was used. Details on the use and acquirement of this free, user-friendly CA program can be found in Lorenzo-Seva, Van de Velden and Kiers [20].

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Appendix 1: Loss of life per location and years (1978-2007)

Locations	1978-87	1988-97	1998-07	Total 1978-07	% to Total	2003	2004	2005	2006	2007	Total 2003-07	% to Total
Arabian Gulf, Indian Ocean, East Africa	454	878	542	1,874	7.6%	15	141	14	108	47	9.3%	454
Australasia, South Pacific, South Pole	8	49	77	134	0.5%	7	3	0	48	1	1.7%	8
Baltic Sea, Kiel Canal	91	1103	30	1,224	5.0%	1	0	1	2	8	0.3%	91
British Isles, North Sea, Engl. Channel, Bay of Biscay	746	351	100	1,197	4.9%	23	5	0	0	1	0.8%	746
Canadian and USSR Arctic and Alaska	60	8	89	157	0.6%	0	52	17	2	7	2.2%	60
Great Lakes	15	3	2	20	0.1%	0	2	0	0	0	0.1%	15
Iceland	45	8	38	91	0.4%	4	19	8	0	0	0.9%	45
Japan, Korea and North China	699	613	557	1,869	7.6%	23	80	89	36	80	8.8%	699
Mediterranean East & Black Sea	892	342	478	1,712	7.0%	68	41	22	22	34	5.3%	892
Mediterranean West	423	367	155	945	3.9%	11	27	31	1	5	2.1%	423
NA East Coast and North Atlantic	342	228	158	728	3.0%	25	22	1	1	0	1.4%	342
NA West Coast and North Pacific	130	12	33	175	0.7%	1	1	0	8	0	0.3%	130
Newfoundland	4	110	23	137	0.6%	0	0	0	1	0	0.0%	4
SA East Coast and South Atlantic	143	73	35	251	1.0%	0	17	0	0	0	0.5%	143
SA West Coast and Panama Canal	44	43	1	88	0.4%	0	0	0	0	0	0.0%	44
South China, Indonesia and Philippines	6644	1527	2172	10,343	42.2%	76	227	226	512	211	35.7%	6644
Suez Canal, Red Sea	21	649	996	1,666	6.8%	0	0	2	989	0	28.2%	21
West African Coast	255	123	1051	1,429	5.8%	22	1	1	2	8	1.0%	255
West Indies and Gulf of Mexico	263	73	136	472	1.9%	4	16	4	6	19	1.4%	263
Total	**11,279**	**6,560**	**6,673**	**24,512**	**100.0%**	**280**	**654**	**416**	**1,738**	**421**	**100.0%**	**11,279**

Note: The portion for the year 1977 is included in 1978 and for 2008 in 2007 since the data is incomplete for these years and only has very few observations for 1997 and 2008

Appendix 2: Pollution per location and years (1978-2007)

Locations	Pollution Quantity (tonnes)					Pollution Type (tonnes)				
	1978-87	1988-97	1998-07	Total 1978-07	% to Total	Chemicals	Heavy & Crude Oil	Light Oil	Other Oil	Other Pollution
Arabian Gulf, Indian Ocean, East Africa	153,950	47,609	61,396	262,956	11.5%	16,004	246,932	0	20	0
Australasia, South Pacific, South Pole	632	18,652	409	19,693	0.9%	0	19,677	17	0	0
Baltic Sea, Kiel Canal	29,772	1,217	3,539	34,528	1.5%	0	34,528	0	0	0
British Isles, North Sea, Engl. Channel, Bay of Biscay	391,416	243,948	23,496	658,860	28.8%	3,813	588,798	29	66,221	0
Canadian and USSR Arctic and Alaska	3,171	38,228	1,466	42,865	1.9%	0	42,863	0	2	0
Great Lakes	443	1,522	224	2,189	0.1%	47	2,081	0	61	0
Iceland	1,147	889	671	2,707	0.1%	0	2,706	0	1	0
Japan, Korea and North China	11,462	10,464	5,894	27,820	1.2%	3,299	22,168	28	2,325	0
Mediterranean East & Black Sea	146,195	12,929	29,278	188,402	8.2%	160	188,139	3	100	0
Mediterranean West	17,028	113,030	741	130,799	5.7%	27	130,763	0	10	0
NA East Coast and North Atlantic	7,997	27,888	25,779	61,665	2.7%	42	36,099	275	25,249	0
NA West Coast and North Pacific	2,692	7,374	746	10,811	0.5%	0	10,375	58	178	200
Newfoundland	6,435	54	58	6,547	0.3%	0	6,542	0	5	0
SA East Coast and South Atlantic	39,835	10,416	1,659	51,909	2.3%	1,024	50,847	0	38	0
SA West Coast and Panama Canal	7,884	1,224	1,104	10,211	0.4%	0	10,211	0	0	0
South China, Indonesia and Philippines	42,270	51,047	29,312	122,629	5.4%	5,310	116,515	21	783	0
Suez Canal, Red Sea	3,643	15,236	0	18,879	0.8%	0	18,879	0	0	0
West African Coast	201,209	15,575	325	217,109	9.5%	0	217,109	0	0	0
West Indies and Gulf of Mexico	365,522	12,688	42,715	420,925	18.4%	347	381,135	8	233	39,203
Total	**1,432,704**	**629,990**	**228,813**	**2,291,506**	**100.0%**	**30,073**	**2,126,368**	**438**	**95,224**	**39,403**

Note: The portion for the year 1977 is included in 1978 and for 2008 in 2007 since the data is incomplete for these years and only has very few observations for 1997 and 2008

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