# Effect and Improvement Areas for Port State Control Inspections to Decrease the Probability of Casualty

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## Abstract

This report is the fourth part of a PhD project called *"The Econometrics of Maritime Safety – Recommendations to Enhance Safety at Sea"* and is based on 183,000 port state control inspections[2] and 11,700 casualties from various data sources. Its overall objective is to provide recommendations to improve safety at sea. The fourth part looks into measuring the effect of inspections on the probability of casualty on either seriousness or casualty first event to show the differences across the regimes. It further gives a link of casualties that were found during inspections with either the seriousness of casualties and casualty first events which reveals three areas of improvement possibilities to potentially decrease the probability of a casualty – the ISM code, machinery and equipment and ship and cargo operations.

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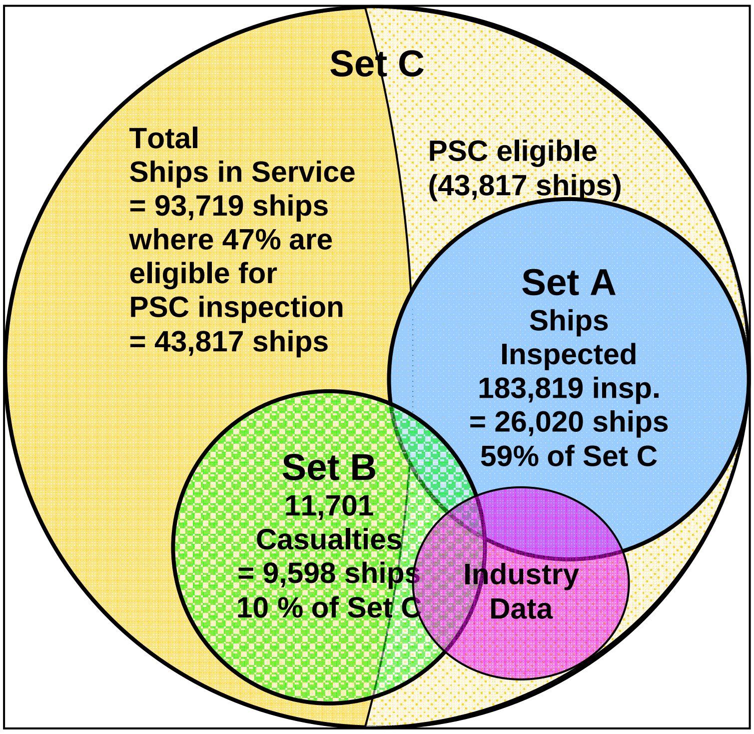
[2] The authors would like to thank the following secretariats for their kind co-operations: Paris MoU, Indian Ocean MoU, Viña del Mar Agreement on PSC, Caribbean MoU, Australian Maritime Safety Authority, the United States Coast Guard, Lloyd's Register Fairplay, Lloyd's Maritime Intelligence Unit, the International Maritime Organization (IMO), Right Ship and the Greenaward Foundation.

## 1. Overview of Datasets and Variables Used

Chapter 1 of this report are extracts from Knapp (2006)[3] which are necessary in order to explain the datasets and variable preparation as a basis for the analysis explained in chapter 3.

Three datasets have been used for the analysis and their relation can be seen in Figure 1. Set A consists of the inspection database of 183,819 inspections from various Memoranda of Understanding (MoU[4]) for the time period January 1999 to December 2004 where the time period is not fully covered by all regimes. This total dataset is a combination of six individual inspection datasets and when aggregated, it accounts for approx. 26,020 ships[5] where the average amount of inspections per vessel is by 7 per ship or 1.7 inspections per ship per year.[6]

**Figure 1: Overview of Datasets Used**



Set C represents an approximation of the total ships in existence[7]. Out of these vessels, ships below 400 gt[8] and ship types which are not eligible for port state control inspection

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[3] Knapp, S. (2006), The Econometrics of Maritime Safety – Recommendations to Enhance Safety at Sea, Doctoral Thesis (to be published), Econometric Institute, Erasmus University, Rotterdam

[4] A memorandum of understanding (MOU) is a legal document describing an agreement between parties but is less formal than a contract.

[5] 25,836 exact ships plus 184 estimated ships. Since there are 1,288 ships with missing IMO numbers out of the total port state control dataset and the average number of inspections per ship lies by 7, the unidentified ships can be aggregated to another 184 inspected ships.

[6] Based on an average of 4 inspection years which is the average of the total months per regime to bring the different years of data to the same level for all regimes. The total time period Jan. 1999 to Dec. 2004 therefore represents a total of full 4 inspection years instead of 6 years.

[7] As per data received from Lloyd's Register Fairplay.

[8] As per Marpol 73/78, Annex I, Regulation 4 which identifies the vessels subject to mandatory surveys (page 51)

such as fishing vessels, government ships, yachts and ferries (for the Paris MoU) have been eliminated from this dataset which leaves approx. 43,817 ships (46,75% of the total) for inspection. Since the amount of inspections from the Paris MoU is the dominating part of this dataset and ferries are treated separately in the EU, ferries have been excluded from PSC eligible ships. The total estimated inspection coverage by the regimes in question of eligible ships is 59.4% between set A and the eligible ships of Set C for the time period in question (1999-2004).

Besides the port state control inspection dataset, a small industry inspection dataset has been collected and comprises of vetting inspection information[9] of vetting inspections performed on oil tankers and dry bulk carriers from Rightship. In addition, oil tankers which are certified by Greenaward have also been identified. The casualty and industry data is linked to the port state control data by the IMO number and within the same time frame.

This total dataset is a combination of six individual inspection datasets and when aggregated, it accounts for approx. 26,020 ships[10] where the average amount of inspections per vessel is 7 per ship or 1.7 inspections per year.[11] Set C represents an approximation of the total ships in existence[12]. Out of these vessels, ships below 400 gt[13] and ship types which are not eligible for port state control inspection such as fishing vessels, government ships, yachts and ferries have been eliminated from this dataset which leaves approx. 44,047 ships (47% of the total) for inspection. The total estimated inspection coverage by the regimes in question of eligible ships lies therefore by slightly above 59% between set A and the eligible ships of Set C.

Set B is the casualty dataset which consists of 11,701 records for time period 1993 to 2004 and is a combination of data received from Lloyd's Register Fairplay, LMIU[14] and the IMO (International Maritime Organization). The time period 2000 to 2004 is the most complete casualty dataset since it draws from all three datasets. Aggregated, this dataset accounts for approx. 9,598 ships or 10% of the total ships in existence from Set C where the average amount of casualties per ship is by 1.2. Port State relevant casualties without the fishing fleet aggregate to 6005 ships for the time period 1999 to 2004 or 13.7% of the total PSC eligible ships.

The sets are used in various ways depending on the kind of analysis which is conducted. In essence the combination of these datasets gives insight into the amount of ships that are inspected/not inspected, detained/not detained and have/do not have a casualty with their respective combinations. Figure 2 gives an overview of the variables used for all types of analysis for port state control and casualties where the link between the two datasets is given by the IMO number and the dates of inspection/casualty respectively.

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[9] Rightship Rating Data (48,834 records of which 37,080 are used) and Greenaward Data on certified ships (244 records)

[10] 25,838 exact ships plus 184 estimated ships. Since there are 1,288 ships with missing IMO numbers out of the total port state control dataset and the average number of inspections per ship lies by 7, the unidentified ships can be aggregated to another 184 inspected ships.

[11] Based on an average of 4 inspection years which is the average of the total months per regime to bring the different years of data to the same level for all regimes. The total time period Jan. 1999 to Dec. 2004 therefore represents a total of full 4 inspection years instead of 6 years.

[12] As per data received from Lloyd's Register Fairplay.

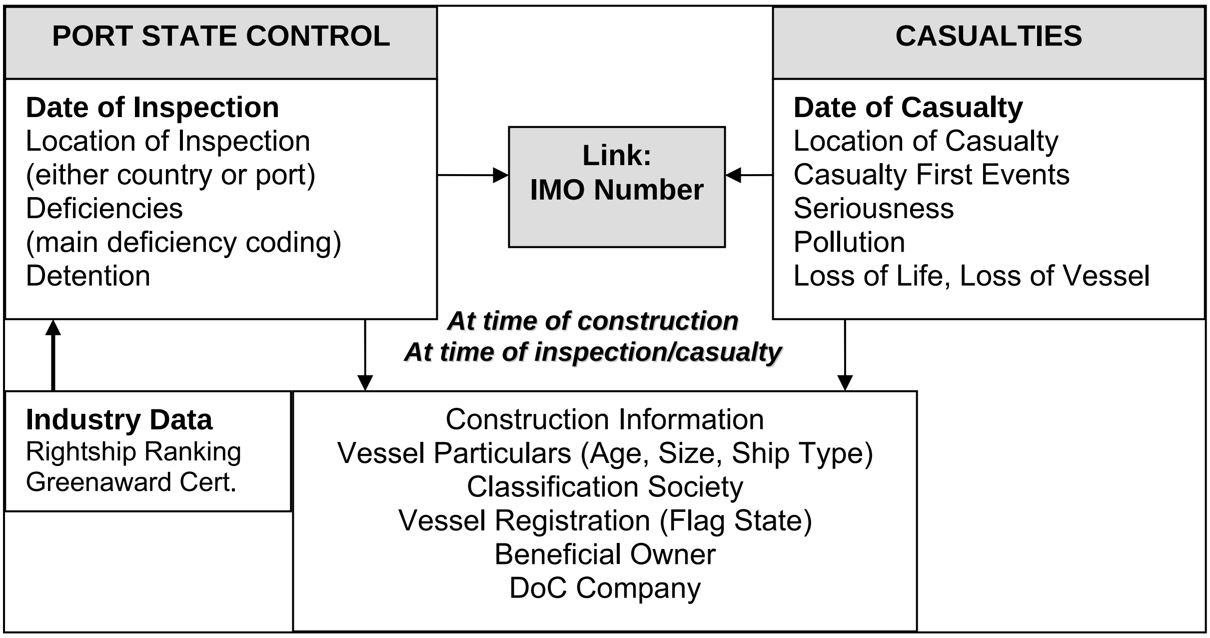
[13] As per Marpol 73/78, Annex I, Regulation 4 which identifies the vessels subject to mandatory surveys (page 51)

[14] Lloyds Maritime Intelligence Unit

This short introduction to the research questions, the methods and datasets used to conduct the analysis should provide enough evidence that the subject is covered from various angles and that great care was placed on the selection of the datasets and the data preparation.

Given the datasets used for the quantitative part, it can be assumed that with almost 60% of coverage of port state control data, a sensible interpretation can be made even with the lack of data from one of the major safety regimes – the Tokyo MoU where cooperation for this analysis unfortunately could not be obtained.

**Figure 2: Overview of Variables Used**



*Note: DoC = Document of Compliance Company, an ISM requirement*

Depending on the type and method of analysis, either dummy variables for each variable are used or the data is coded into groups (e.g. flag states can be used individually or grouped into black, grey or white listed flag states). The incorporation of the ownership of a vessel is not a straight forward task in shipping and requires some careful thinking. Two types of variable groups have therefore been used. The first one is information concerning the Document of Compliance Company (DoC) of a vessel based on information received from Lloyd's Register Fairplay and the second one and due to the lack of the completeness of information on the DoC Company is the addition on the ownership of a company which represents the "beneficial owner"[15]. Variable transformation and regrouping was performed for port state control data and casualty data. Transformation tables were used to re-code all of the following variables:

1) Flag States (Black, Grey, White, Undefined) – Paris MoU
2) Classification Societies – IACS and Not IACS recognized
3) Ownership of a vessel as per Alderton & Winchester or technical management as per LR Fairplay (DoC Company)
4) Ship Types

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[15] based on Lloyd's Register Fairplay data of the "World Shipping Encyclopedia CD" and Lloyd's "Maritime Database CD"

Variables were recoded using a transformation table for each MoU and the casualty datasets into standard codes for each variable group (flag, class, owner, ship type). The standard coding used for the total datasets were then transferred into dummy variables for the regressions or descriptive statistics.

### *Flag States*

Flag States were coded individually or grouped into four major groups according to the Paris MoU Black, Grey and White List[16] where white listed flag states are performing well followed by grey. Black listed flag states are performing worst. Flag states in the group "undefined" are flag states that do not have enough inspections for the Paris MoU or do not trade in the Paris MoU area.

### *Classification Societies (RO)*

Classification Societies have been coded individually or grouped into two groups – either they are a member of the International Association of Classification Society or not which serves as a kind of quality indicator. There are currently ten members as follows:[17]

1) American Bureau of Shipping
2) Bureau Veritas
3) China Classification Society
4) Det Norske Veritas
5) Germanischer Lloyd
6) Korean Register of Shipping
7) Lloyd's Register
8) Nippon Kaiji Kyokai (ClassNK)
9) Registro Italiano Navale
10) Russian Maritime Register of Shipping

### *Ownership or Technical Management*

Ownership is represented by two variables. It is either the "true owner" (not the registered one) who has the financial benefit or it is the technical manager on the ISM Document of Compliance[18] The datasets were merged with data from Lloyds Register Fairplay in order to identify the ownership of a certain vessel for both variables. For the true ownership, the country of location was then grouped according to Alderton and Winchester (1999)[19] to reflect the safety culture onboard. The grouping of the countries into six main groups is found in Appendix 1 for further reference but is as follows:

- traditional maritime nations
- emerging maritime nations
- new open registries
- old open registries
- international open registries
- "unknown" for unknown or missing entries.

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[16] Paris Memorandum of Understanding Annual Reports for 2000 – 2004.

[17] As per IACS, http://www.iacs.org.uk

[18] The Document of Compliance is a requirement by the ISM (International Safety Management Code) Code. The technical manager responsible for the safety management of the vessel needs to be identified on this document. Sometimes for smaller companies, this can be the owner; otherwise it is contracted out to manager who runs the vessel on behalf of the owner.

[19] Alderton T. and Winchester N (2002). "Flag States and Safety: 1997-1999". *Maritime Policy and Management*, Vol 29, No. 2, pp 151-162

***The Selection of Ship Types***

The selection of ship types for the analyses is important and therefore considerable amount of time was spent to find the best possible grouping. This provides a more accurate analysis of the probability of detention. The decision was based on five points as follows:

- *Point 1:* Legal Base including the major conventions and related codes distinguishing different applications based on ship types and the deriving differences in conducting a port state control inspection.
- *Point 2:* World Trade Flows to capture exposure of the regimes in connection with the % of ship types that were inspected/detained by each regime and the special commercial characteristics of each segment
- *Point 3:* Analysis of Casualties per ship type and their severity
- *Point 4:* Analysis of Regression Results of port state control data for each ship type and in aggregated version
- *Point 5:* Correspondence Analysis based on port state control data in order to visualize the effects on aggregating the data and to provide an overall confirmation on the selection of the grouping of ship types.

Taking the decision points listed above into account where the detailed analyses involved to derive at the grouping is shown in Knapp (2006) in detail, the following ship types have been aggregated out of the 19 original ship types:

1. **General Cargo & Multipurpose** (General Cargo, Ro-Ro Cargo, Reefer Cargo, Heavy Load)
2. **Dry Bulk**
3. **Container**
4. **Tanker** (Tanker, Oil Tanker, Chemical Tankers, Gas Carriers, OBO)
5. **Passenger Vessel** (Passenger Ships, Ro-Ro Passenger, HS Passenger)
6. **Other** (Offshore, Special Purpose, Factory Ship, Mobile Offshore, Other Ship Types)

## 2. Descriptive Statistics and Key Figures for Casualties

### *2.1. Selection of Port State Control Relevant Casualties*

Considerate care was given on the selection of casualties for the analysis. From the casualty dataset within the time period 1999 to 2004 of 9,851 cases, the following cases were eliminated.

1. Cases due to extreme weather conditions such as hurricanes, typhoons, gales and very heavy storms
2. Ships attacked by pirates or ships lost due to war
3. Ships involved in a collision with no identified fault[20]
4. Any other miscellaneous items not relevant to PSC such as drugs found, virus outbreaks of passengers or accidents which happened in dry docks
5. Not PSC relevant ships types such as ferries, the fishing fleet, tugs or government vessels. The fishing fleet cases were kept separate and a separate analysis was performed based only on the fishing fleet above 400gt.

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[20] The identification of “no fault” in this case was not straight forward and some cases still included in the dataset might be ships with no fault and were not eliminated due to lack of exactness of data.

The remaining 6291 cases concern 6,005 ships when aggregated by IMO number and were then reviewed and re-grouped into the three groups of seriousness as per IMO MSC Circular 953 of December 2000:[21]

1. ***Very serious casualties:*** casualties to ships which involve total loss of the ship, loss of life or severe pollution
2. ***Serious casualties*** are casualties to ships which do not qualify as "very serious casualties" and which involve fire, explosion, collision, grounding, contact, heavy weather damage, ice damage, hull cracking, or suspected hull defect, etc. resulting in: immobilization of main engines, extensive accommodation damage, severe structural damage, such as penetration of the hull under water, etc. rendering the ship unfit to proceed, or pollution (regardless of quantity); and/or a breakdown necessitation towage or shore assistance.
3. ***Less serious casualties*** are casualties to ships which do not qualify as "very serious casualties" or "serious casualties" and for the purpose of recording useful information also include "marine incidents" which themselves include "hazardous incidents" and "near misses".

In addition to the classification of seriousness of casualties, the cases were also examined and re-classified according to casualty first events. The casualty first events are classified as follows:

- *Deck and Hull related casualties:* Deck and hull related items such as maintenance items (cracks, holes, fractures, hatch cover problems, cargo equipment failure, lifeboat gear failure, anchor and mooring ropes problems), stability related items such as capsizing, listing, cargo shifts and flooding
- *Fire/Explosion:* Fire and Explosion anywhere on the vessel (main areas are engine room)
- *Engine or machinery related casualties:* Engine related items including engine breakdown, black outs, steering gear failure and propulsion failure
- *Wrecked/Stranded/Grounded:* Wrecked, Stranded, Grounded where a large portion of the ships in this category are stranded or grounded. 112 ships in this category are ships that were lost and therefore could probably be classified as wrecked. Nevertheless, for the purpose of the analysis, this category is to be interpreted primarily for stranded and grounded vessels.
- *Collision and Contact:* Collision and Contact

Figure 3 then gives an overview of the split up of the casualty first events. The graph is not detailed but can be understood as a first attempt to break up the casualty types into relevant categories.

The lack of information and fragmentation of the data does not permit a better split up. Interesting to see is the high amount of engine and machinery related events of about 32% (engine breakdown, engine black out, steering gear failure and propulsion failure) while the probability of detention has shown a relative low probability of detention based on deficiencies in the area of propulsion and auxiliary machinery (code 1400).

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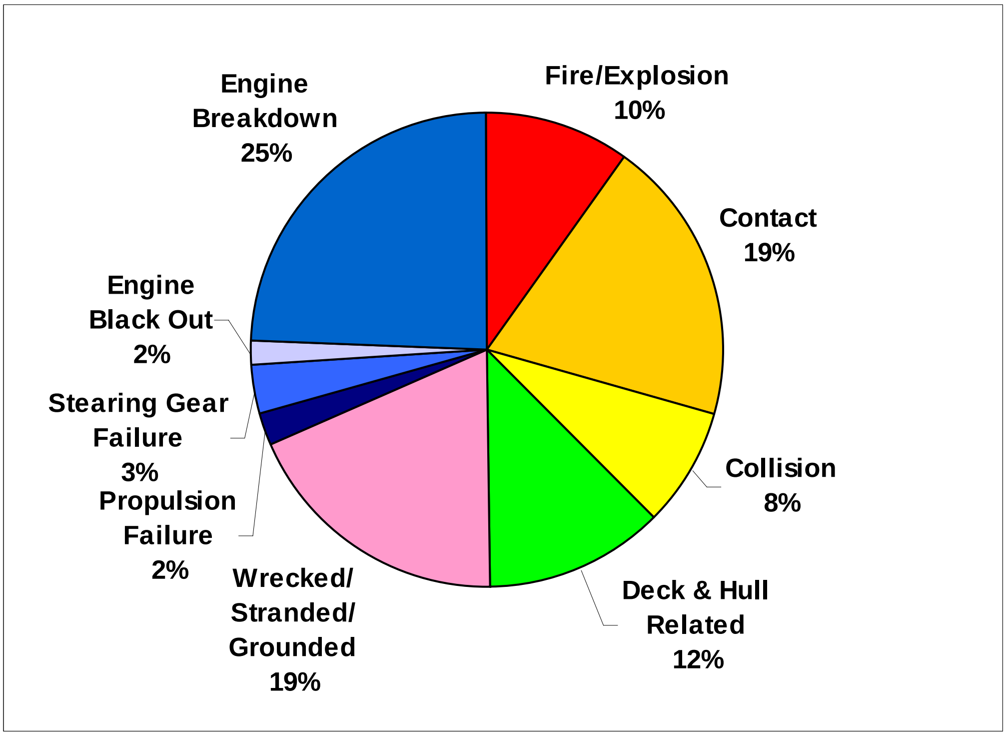
[21] as per IMO MSC Circular 953, 14th December 2000

**Figure 3: Casualty First Events per Ship Type (1999 to 2004)**

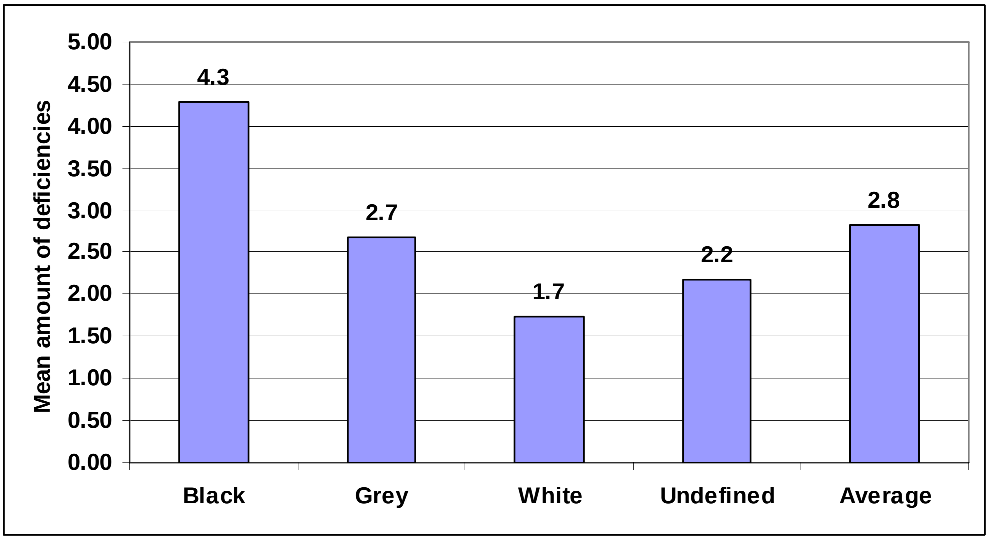


*PSC Relevant Cases, compiled by author*

## *2.2. Overview of Deficiencies and Casualties*

Figure 4 gives an overview of the mean amount of deficiencies found six month prior to a casualty per flag state group while Figure 5 shows the split up for IACS recognized classification societies and non IACS recognized classification societies.

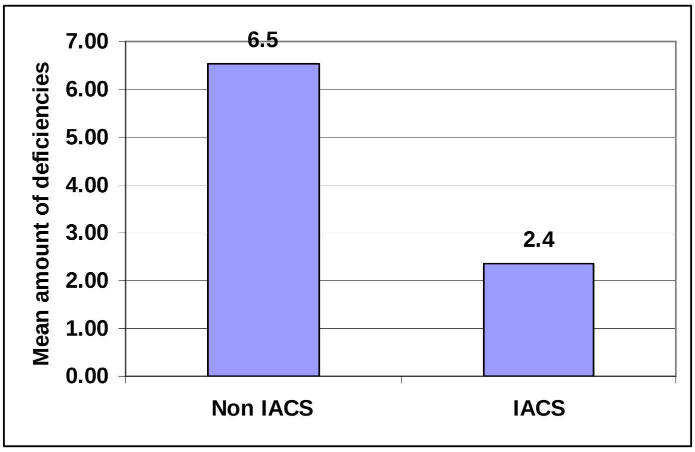
**Figure 4: Mean Amount of Deficiencies per Flag State: 6 months prior to casualty**



*Note: based on ships that were inspected six month prior to casualty*

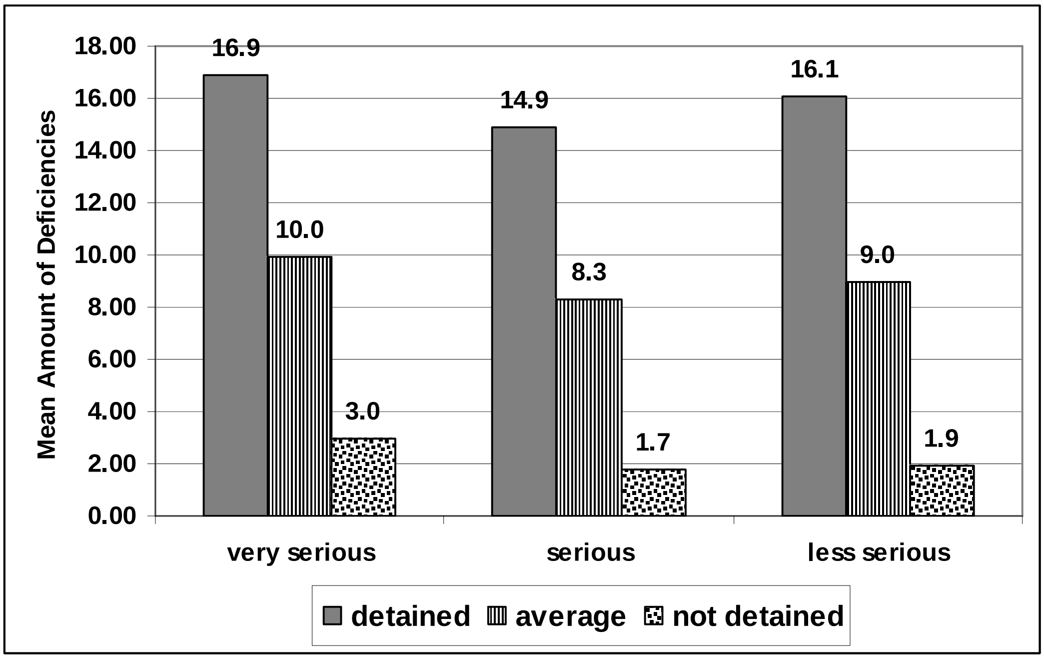
Black listed flag states have an average of 4.3 deficiencies versus 1.7 deficiencies for white listed flag states. Ships of Non-IACS classification societies have an average of 6.5 deficiencies versus 2.4 for ships with ICAS classification in an inspection at least six months prior to a casualty. Figure 6 shows the mean amount of deficiencies that are found previous to a casualty per seriousness of casualty and detention. Ships that have been detained show a significant higher amount of deficiencies than ships that have not been detained prior to a casualty.

**Figure 5: Mean Amount of Deficiencies per Class: 6 months prior to casualty**



*Note: based on ships that were inspected six month prior to casualty*

**Figure 6: Mean Amount of Deficiencies per Seriousness of Casualty**



*Note: based on ships that were inspected six month prior to casualty*

The next chapter will provide the probability of casualty as refined view and based on either seriousness or casualty first event. It further provides models which link the deficiencies found during and inspection with the casualty first events to identify room for improvements of inspections.

# 3. The Probability of Casualty – Refined View

## *3.1. Description of Model and Methodology*

This model will provide the estimated probability ($P$) of a ship having a casualty based on each ship type defined previously for each safety regime. The dependent variable ($y$) in this case is "casualty" or "no casualty". In a binary regression, a latent variable $y^*$ gets mapped onto a binominal variable $y$ which can be 1 (casualty) or 0 (no casualty). When this latent variable exceeds a threshold, which is typically equal to 0, it gets mapped onto 1, other wise onto 0. The latent variable itself can be expressed as a standard linear regression model

$$y^*_i = x_i\beta + \varepsilon_i$$

where $i$ denotes ship $i$. The $x_i$ contains independent variables such as age, size, flag, classification society or owner, and $\beta$ represents a column vector of unknown parameters (the coefficients). The binary regression model can be derived as follows:[22]

$$P\,(y_i = 1 \mid x_i) = P\,(y^*_i > 0 \mid x_i) = P\,(x_i\beta + \varepsilon_i > 0 \mid x_i) = P\,(\varepsilon_i > -\,x_i\beta \mid x_i) = \mathrm{P}\,(\varepsilon_i \leq x_i\beta \mid x_i)$$

The last term is equal to the cumulative distribution function of $\varepsilon_i$ evaluated in $x_i\beta$, or in short:

$$P\,(y_i = 1 \mid x_i) = \mathrm{F}\,(x_i\beta)$$

This function $F$ can take many forms and for this study two were considered, namely the cumulative distribution function of the normal distribution (probit model) and the cumulative distribution function of the logistic function (logit model). The general model can therefore be written in the form of Equation 1 where the term $x_i\beta$ changes according to the model in question.

**Equation 1: Probability of Casualty (per seriousness)**

$$P_{\mathrm{i}} = \frac{\mathrm{e}^{(x_i\beta)}}{1 + \mathrm{e}^{(x_i\beta)}}$$

To estimate the coefficients, quasi-maximum likelihood (QML)[23] is used as method of estimation in order to give some allowance for a possible misspecification of the assumed underlying distribution function. For the final models, logit and probit models are compared to see if there are any significant differences and logit models are used for the visualization part.

Figure 7 provides an overview of the steps that were taken in order to perform the analysis which will be described in the next chapter.

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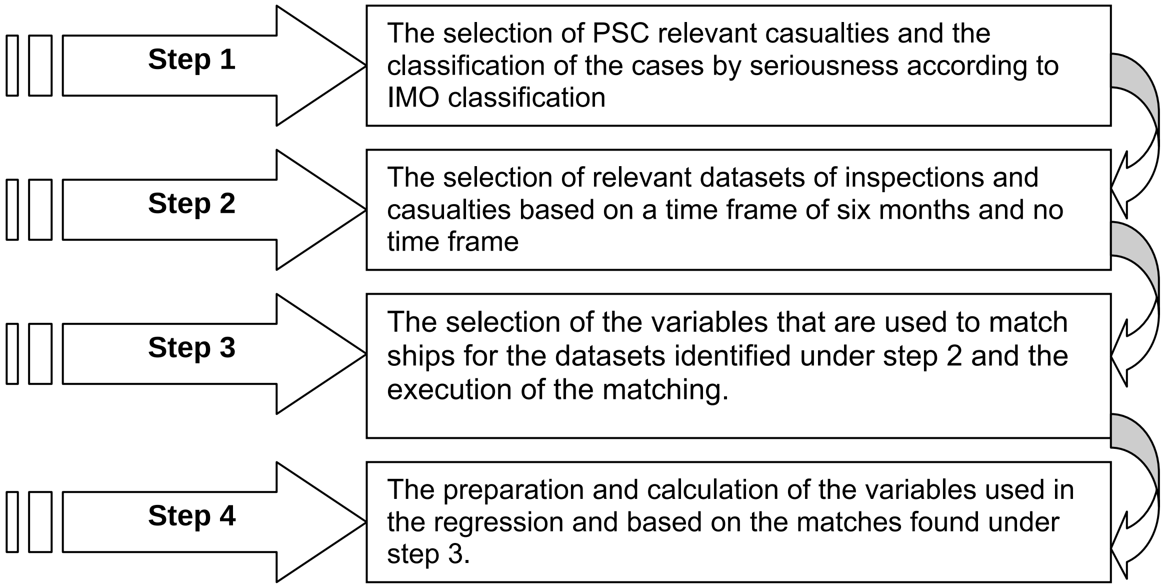
[22] for further reference, refer to Franses, P.H. and Paap, R. (2001). *Quantitative Models in Marketing Research.* Cambridge University Press, Cambridge, Chapter 4

[23] for further details on QML, refer to Greene H.W. (2000), *Econometric Analysis*, Fourth Edition, page 823ff

The *first step* is the same as mentioned in the previous chapter and will therefore not be explained again in detail. The bases for the casualties are all ships with port state control relevant casualties – a total of 6,005 ships.

**Figure 7: Description of Methodology Used**



The selection of PSC relevant casualties and the classification of the cases by seriousness according to IMO classification

The selection of relevant datasets of inspections and casualties based on a time frame of six months and no time frame

The selection of the variables that are used to match ships for the datasets identified under step 2 and the execution of the matching.

The preparation and calculation of the variables used in the regression and based on the matches found under step 3.

### *3.2. Explanation of Relevant Datasets and Procedure to Match Ships*

The *second step* was then to link the ships with a casualty to the ships without casualty and 3,956 ships emerged to show a connection based on the IMO number and were taken into further consideration. These vessels provide the basis for several merges within a certain time frame in order to gain a better overview of the connection between casualties and port state control inspections. The following results are listed in Table 1 below.

**Table 1: Datasets for Port State Control and Casualty Merges Performed**

| Datasets | Criteria Used for Data Links | Total Inspections | Total Casualties | Total Records | Total Ships |
|---|---|---|---|---|---|
| Set 1 | Inspections with no casualties | 148,557 | Nil | 148,557 | 21,880 |
| Set 2A | Time Frame: 6 months | 23,401 | 2,921 | 26,322 | 2,321 |
| Set 2B | No Time Frame | 33,974 | 4,737 | 38,711 | 3,956 |

The datasets show three scenarios where set 2B does not contain any particular time frame between an inspection and a casualty. The remaining set is based on a minimum of at least one connection of an inspection prior to a casualty of 6 months. After this merge was performed, the remaining inspections and if applicable casualties of a particular vessel were added in order to account for the whole inspection history of a vessel.

*Step 3* is the starting point to create a dataset which is then used in the analysis. The idea is to match ships from the datasets described earlier, and which had casualties, with ships that did not have casualties. In order to match ships from each of the groups, a set of variables had to be identified to guarantee the best possible match.

These variables are assumed not to have a direct impact on the seriousness of a casualty and are listed in order of importance given the fact that the difference of observations in the datasets is quiet large. In doing the match, the first three variables are the most important ones followed by the country the ship was constructed and the owner and then the remaining variables such as class, flag and hull details for tankers.

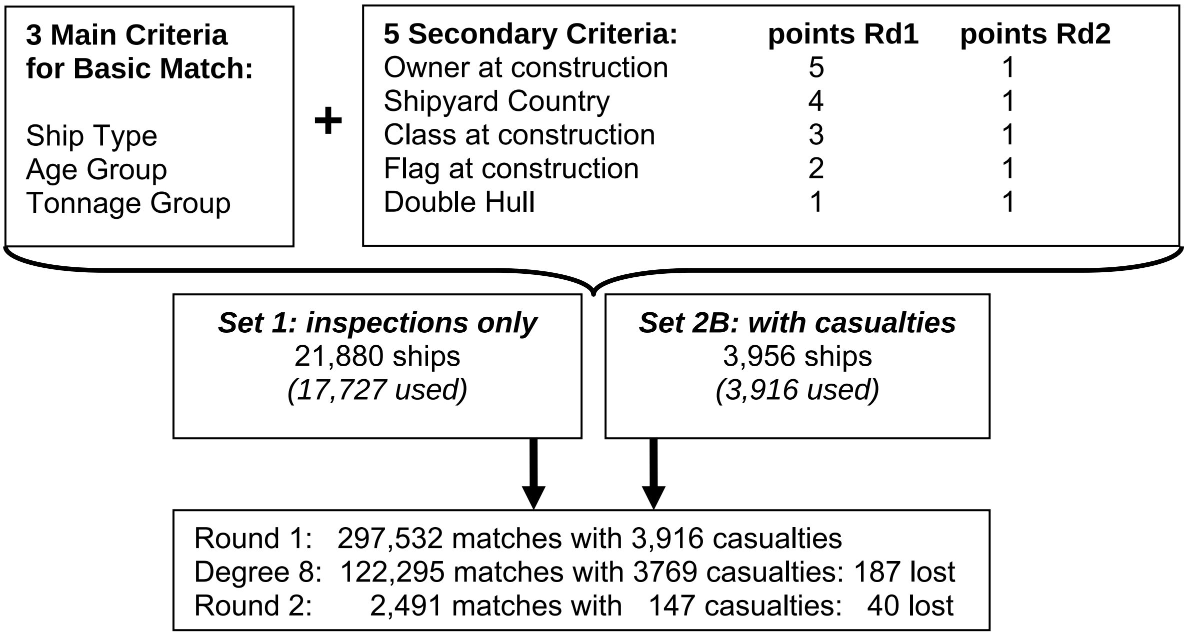
**Table 2: List of Variables used to Match Ships**

| |
|---|
| 1. Ship Type at the time of construction |
| 2. Year Built (in 11 ranges) |
| 3. Gross Tonnage (in 44 ranges) |
| 4. Country of Owner at time of construction |
| 5. Country where Ship was primarily built |
| 6. Class at construction |
| 7. Flag at construction |
| 8. Double Hull |

Ship type is found to be the most important variable for determining the construction quality and operating environment of a ship. Out of the total 25,836 ships from the inspection dataset, 1546 ships were converted or alternated since construction and 290 ships changed their ship type completely.

The matching was performed between Set 1 and Set2B using Oracle[24] and following the methodology which is visualized in Figure 8. Set 2A is a subset of Set 2B and is then extracted from the result of the basic match performed on Set 2B. The match was performed in two rounds where double matches for ships with casualties are allowed out of the dataset of ships with inspections only. The first round matches the vessels on the three basic criteria listed in the figure namely: ship type, age and tonnage. From the 21,880 available ships, 17,727 were used to match and 4,153 records were not used.

**Figure 8: Visualization of Matching Methodology (per Ship)**



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[24] Credit is given here to *Ratan Singh Ratore* who assisted the author in performing this match by providing the necessary software (Oracle) and SQL statements to execute the queries.

This is then followed by a refinement of the matches using the remaining criteria in order of importance with weighted points. The basic match comes up with 297,532 matches for 3,916 ships with casualties. The refinement match based on ownership (5 points), the ship yard country (4 points), the class at construction (3 points) and the flag state at construction (2 points) reduces the basic matches to 122,295 hits with 3,769 ships with casualties by using a degree 8 to match ships. The decision to allocate points is not based on any empirical evidence of the impact of the variables on the construction quality. It is based on the author's understanding of the shipping industry and partly derived from interviews[25] with surveyors who have experience with new buildings, naval architects and one of the ship owner's associations[26].

Degree 8 means that the matching ships have both eight points out of the total of 15 points which would be a perfect twin. Several scenarios were run using various degrees of matching before a decision was made to use degree eight for the analysis and the results are shown in Table 3. The table lists the degrees of matches (as total points of the point allocated per additional criteria), the matches of ships with inspections, the number of ships with casualties that were used and not used and the % of casualties that are lost to the total casualties (3,956).

The last column indicates which of the scenarios is then accepted for the analysis. Degree eight was chosen because it provides a balanced result of loosing 4.7% of the cases with casualties by having a matching degree of 8 points out of 15 total points where eight points means that at least three out of the five additional criteria are matched besides the three basic criteria.

With degree 8, 187 ships did not have a corresponding ship. Since 23 cases are very serious casualties and 115 cases serious casualties, a second round of matching was performed on these ships by using a simplified point system for the remaining criteria (1 point instead of the weighted point system). The resulting basic match based on degree 1 (at least two more variables match besides the three basic ones) reveals 2,491 hits with 147 ships with casualties.

**Table 3: Summary of Matches by Degrees for Round 1(by Ship)**

| Degrees of Match | Ships with Inspections Matched | Ships with Casualties Used | Ships with Casualties Not Used | % Ships Lost to Total (3,956) | Dataset Used for Analysis |
|---|---|---|---|---|---|
| 15 | 6,840 | 1,757 | 2,199 | 55.5% | Yes |
| 14 | n/a | 1,788 | 2,168 | 54.8% | No |
| 13 | n/a | 2,829 | 1,127 | 28.5% | No |
| 12 | n/a | 3,021 | 935 | 23.6% | No |
| 11 | n/a | 3,166 | 790 | 19.9% | No |
| 10 | 47,768 | 3,394 | 562 | 14.2% | No |
| 9 | 106,658 | 3,720 | 236 | 5.9% | No |
| 8 | 122,295 | 3,769 | 187 | 4.7% | Yes |
| 7 | 124,172 | 3,781 | 175 | 4.4% | No |

A total of 40 ships do not have any corresponding vessel out of the inspection dataset. From these 40 ships, 6 had a very serious casualty, 24 a serious casualty and 10 a less serious casualty. These 40 ships are not used in the analysis. The final results of the match are presented in Table 4 and are based on ship counts (a ship can have several

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[25] For detailed list of interviews performed by the author can be found in the Bibliography.

[26] Dutch Royal Ship Owner's Association

casualties). The column indicating the ships with casualties lost is based on the number of ships with casualties as listed in Table 1 and the actual number of ships that found matches. This match provides the basis for the models that will follow. In addition to the six months time frame, a separate match was performed based on perfect twins instead of degree 8 in order to see if enough observations are available to use this dataset. From the total amount of observations of 8,597 cases in comparison to 77,599 cases, one can easily see that the amount of observations is limited. It is therefore decided to only use the dataset based on degree 8 and with the time frame of six months prior to a casualty.

**Table 4: Summary of Matched Datasets (by Ship)**

| **Final Datasets** | **Ships with Inspections Round 1 & 2** | **Ships with Casualties Round 1 & 2** | **Ships with Casualties Lost** | **Total Dataset Cases** |
|---|---|---|---|---|
| No Time Frame | 124,786 | 3,916 | 40 | 128,702 |
| 6 months | 75,302 | 2,297 | 24 | 77,599 |
| Perfect Twins | 6,840 | 1,757 | n/a | 8,597 |

Table 5 gives an overview of the types of models that are used. The table lists the types of models with the total amount of regressions in each series, the datasets on which the models are based on and the variables that are of interest in each of the regressions. Type I model is based on the seriousness of casualty and should give an overview of the effectiveness of an inspection (per regime) on the probability of either a very serious, serious or less serious casualty. Type II is an aggregated model which uses multiplicative dummy variables for the deficiencies and ship types in order to see if there are any significant differences with respect to deficiencies found before an inspection and the ship types. It can be seen as a further refinement of the type I models but only for very serious and serious casualties.

**Table 5: List of Twin Models and their Variables of Interest**

| **Model Name** | **Types of Model/Data based on** | **Variables of interest** |
|---|---|---|
| **Type I Models**<br>(Total Models: 3) | Based on twins of ships inspected six months prior to a casualty<br>Types are as follows*):<br>o Very serious (5,826)<br>o Serious (45,486)<br>o Less serious (27,411) | Time in-between inspection<br>Detention<br>Deficiencies (less serious)<br>Regimes (overall view)<br>Vetting Inspections |
| **Type II Model**<br>(Total Model: 1) | Based on twins of ships inspected six months prior to a casualty but combined of very serious and serious casualties in order to increase the amount of observations. The deficiencies are multiplied by ship types and used as multiplicative dummies<br>Total # of observations: (52,150) | Time in-between inspection<br>Detention<br>Deficiencies per ship type<br>Regimes (overall view) |
| **Type III Models**<br>(Total Models: 5) | Based on casualties of a respective first event in relation to the deficiencies found during a PSC inspection. Types are as follows:<br>o Fire & Explosion (6,218)<br>o Wrecked/Stranded/Grounded (19,131)<br>o Collision/Contact (23,254)<br>o Deck Related First Events (8,357)<br>o Engine Related First Events (27,079) | Time in-between inspection<br>Detention<br>Deficiencies (refined view)<br>Regimes (overall view) |

**) Note: the numbers in brackets are number of observations in the model*

The type III models are based on the casualty first events identified at the beginning of this report and are a first attempt to link the deficiencies with casualties. The next section will explain the variables and the base model itself which is then applied according to the type I, II or III models.

### *3.3. Explanation of Variables used in the Models*

The variables listed in Table 6 are a summary of the variables that are used in the regressions. The variables are split into two blocks where block 1 contains the variables which are normally used to target vessels such as the ship type, the classification society, the flag state and the ownership of a vessel and block 2 provides a summary of the inspection history of a particular vessel including information on industry inspections (vetting inspections of Rightship and Greenaward).

**Table 6: Variables Used in the Twin Regressions (Type I, II and III models)**

| | | **Dependent Variable 1: Casualty:**<br>*This can be either per seriousness or by casualty first event* | | | **1/0** |
|---|---|---|---|---|---|
| | | **Independent Variables** | **Number of Variable nℓ** | **Remark on Variable** | **Expected Sign** |
| | **ℓ** | ***Block 1: Ship Particulars: included to account for target factors*** | | | |
| Ln(Age) | 1 | Average age at Inspection | 1 | C | |
| Ln(SIZE) | 2 | Gross Tonnage | 1 | C | |
| ST | 3 | Ship Type at present | 6 | D | |
| STInd | 4 | Ship Type Changed | 1 | D | |
| CL | 5 | Classification Society at inspection | 33 | D | |
| CLInd | 6 | Classification Society changed | 1 | D | |
| CLWdr | 7 | Class Withdrawn | 1 | D | |
| FS | 8 | Flag State at inspection | 81 | D | |
| FSInd | 9 | Flag State Changed | 1 | D | |
| OWN | 10 | Owner of vessel | 6 | D | |
| OWNInd | 11 | Ownership changed | 1 | D | |
| LIOWN | 12 | Legal Instruments Rectified (Owner) | 1 | C | |
| LIFS | 13 | Legal Instruments Rectified (Flag) | 1 | C | |
| DH | 14 | Double Hull | 1 | D | |
| | | ***Block 2: Inspection History: variables of interest*** | | | |
| RS | 15 | Rightship Inspected (5 Star Rating or indicator) | 5 | D | neg |
| GR | 16 | Greenaward Certified | 1 | D | neg |
| ln(TIME) | 17 | Time in between inspections (days) | 1 | C | neg |
| PSC | 18 | Inspections Frequency per Regime (Fractions) | 6 | D | neg |
| DETPS | 19 | Detention Frequency per Regime | 6 | D | neg |
| CODE | 20 | Deficiency main codes (also multiplied by ST) | 26 (156) | C | und |
| | | **Total Variables*)** | **181(311)** | | |

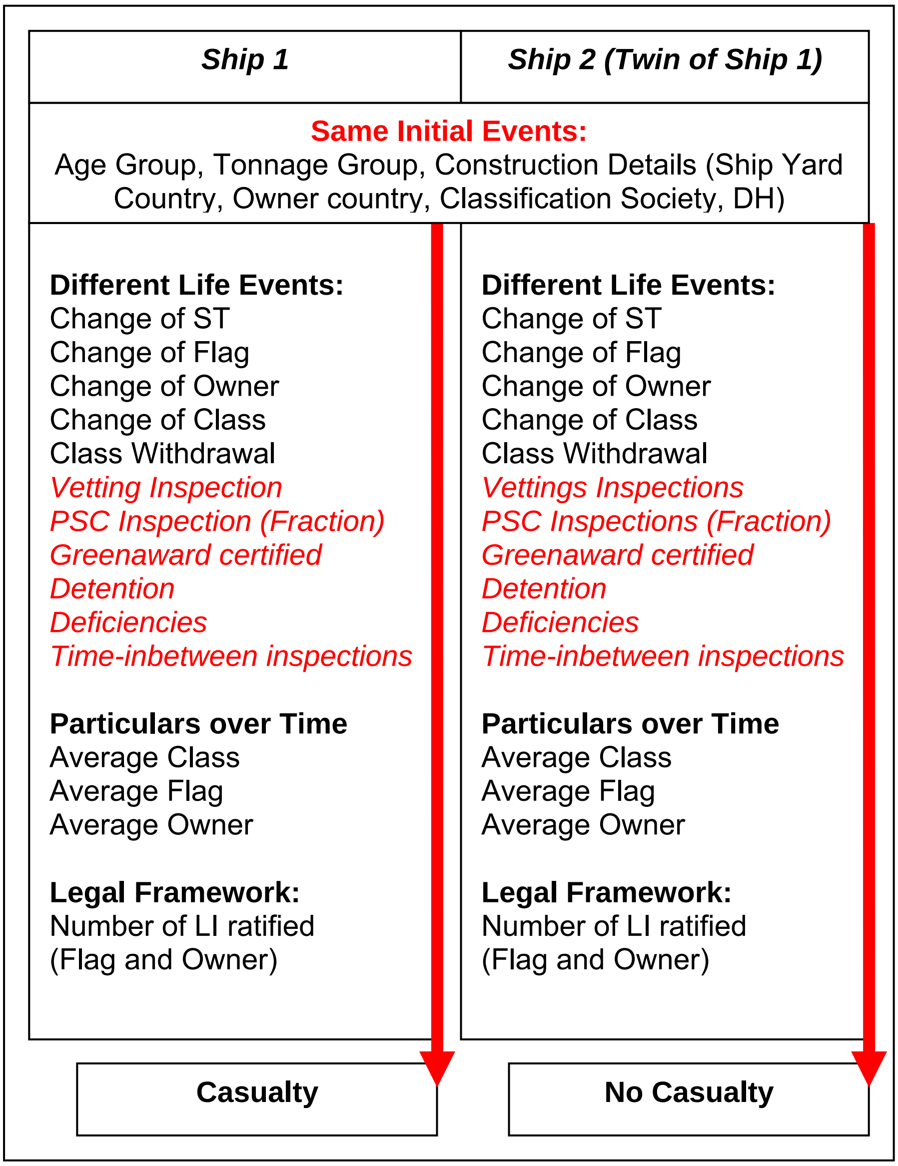
**) in brackets indicates number of multiplicative dummy variables*
*C= Continuous, D= Dummy*

Within block 1, changes in any of the variables since the construction of the vessel and during the years of inspection history are identified (e.g. the ship type was converted, flag, class or ownership changed). This block also includes information the number of legal instruments a certain flag or country of residence of an owner has rectified.

Since the whole inspection and casualty history of a particular vessel is taken into consideration, average percentage fractions over all records of one particular vessel (aggregated by IMO number) are used in the regressions for the inspections and the detentions while the deficiencies are aggregated and represent a total sum. In addition and depending on the final model, the variables indicating where the ship was inspected can be replaced by the actual port states and the deficiencies can be multiplied by ship types and therefore increases the amount of variables accordingly. The increased amount of variables is shown in brackets in the table.

Figure 9 visualizes the variable structure of the twin models by following a time line of a pair of vessels over its course of life and the model can be written in the form of Equation 1 where the term $x_i\beta$ can change accordingly to the casualty model in question (either per seriousness of casualty or by casualty first event) and is given in Equation 2 and its variables are further explained in Table 6.

**Figure 9: Visualization of Variable Structure: Twin Models**



*Note: Variables of interest are in italic*

**Equation 2: Detailed Effect of Inspections (Seriousness or First Event)**

$$
\begin{aligned}
x_{\mathrm{i}}\beta = {} & \beta_0 + \beta_1 \ln(\mathrm{AGE}_i) + \beta_2 \ln(\mathrm{SIZE}_i) + \sum_{k=1}^{n_3-1} \beta_{3,k}\,\mathrm{ST}_{k,i} + \beta_4\,\mathrm{STInd}_i \\
& + \sum_{k=1}^{n_5-1} \beta_{5,k}\,\mathrm{CL}_{k,i} + \beta_6\,\mathrm{CLInd}_i + \beta_7\,\mathrm{CLWdr}_i + \sum_{k=1}^{n_8-1} \beta_{8,k}\,\mathrm{FS}_{k,i} \\
& + \beta_9\,\mathrm{FSInd}_i + \sum_{k=1}^{n_{10}-1} \beta_{10,k}\,\mathrm{OWN}_{k,i} + \beta_{11}\,\mathrm{OwnInd}_i + \beta_{12}\,\mathrm{LIOWN}_i \\
& + \beta_{13}\,\mathrm{LIFS}_i + \beta_{14}\,\mathrm{DH}_i + \sum_{k=1}^{n_{15}-1} \beta_{15,k}\,\mathrm{RS}_{k,i} + \beta_{16}\,\mathrm{GR}_i + \beta_{17} \ln(\mathrm{TIME}_i) \\
& + \sum_{k=1}^{n_{18}-1} \beta_{18,k}\,\mathrm{PSC}_{k,i} + \sum_{k=1}^{n_{19}-1} \beta_{19,k}\,\mathrm{DETPS}_{k,i} + \sum_{k=1}^{n_{20}} \beta_{20,k}\,\mathrm{CODE}_{k,i}
\end{aligned}
$$

The model produces probabilities on an individual ship level ($i$). The rest of the notation is as follows: $\ell$ represents the variable groups, $n_\ell$ is the total number of variables within each group of $\ell$ and $k$ is an index from 1 to $n_\ell$

### *3.4. Model Evaluation and Final Results (type I, II and III models)*

Table 7 provides a split up of the ships with casualties into their seriousness which is the basis for the type I and II models.

**Table 7: Summary of Matched Dataset by Seriousness of Casualty (by Ship)**

| **Final Datasets** | **Very Serious** | | **Serious** | | **Less Serious** | |
|---|---|---|---|---|---|---|
| ***By Seriousness*** | ***Casualties*** | ***Total Cases*** | ***Casualties*** | ***Total Cases*** | ***Casualties*** | ***Total Cases*** |
| No Time Frame | 306 | **10,778** | 2,345 | **77,980** | 1,457 | **44,882** |
| 6 months | 167*) | **6,007** | 1,387 | **46,522** | 881 | **28,008** |
| Perfect Twins | 156 | **958** | 1,033 | **4,824** | 641 | **3,091** |

**) Note: figures are with passenger vessels and the Caribbean MoU while final models are without these variables due to lack of data*

Type II is based on a combined dataset for very serious and serious casualties. The figures are based on the number of ships and since a ship can have multiple casualties, some ships are counted in each of the casualty categories. The table provides the number of ships with a certain type of casualty and the corresponding total cases (ships with casualties and inspections).

The type III models are a series of five regressions which link casualty first events with deficiencies that are found previously. The basis for these regressions is all ships that were inspected six month prior to a casualty, a total of 2321 ships. The corresponding datasets are listed in Table 8 below.

**Table 8: Summary of Matched Dataset by Casualty First Events (by Ship)**

| Casualty First Event | Casualties | Twins | Total Obs |
|---|---|---|---|
| Fire/Explosion | 213 | 6005 | 6218 |
| Wrecked/Stranded/Grounded | 526 | 18605 | 19131 |
| Collision/Contact | 713 | 22541 | 23254 |
| Deck Related | 253 | 8104 | 8357 |
| Engine Related | 819 | 26260 | 27079 |

**) Figures are with the Caribbean MoU and all ship types while final model can vary accordingly*

All models were tested for the presence of heteroscedasticity using the LM test as described by Davidson and McKinnon (1993)[27]. The null hypothesis ($h_o$) assumes homoscedasticity and the alternative hypothesis assumes heteroscedasticity in the following form where $\gamma$ is unknown and $z$ are a number of variables which are assumed to be the cause of heteroscedasticity:

$$\text{Variance} = \exp(2z'\gamma)$$

A summary of the findings can be seen in Table 9 for the type I and type II models where $h_o$ is rejected only for tonnage in the type II model. Based on Knapp (2006, chapter 6)[28] where probabilities were calculated based on a model developed by Greene[29] and based on Harvey (1976) and no significant difference was found between the normal and the corrected model, it is assumed that the presence of heteroscedasticity for the variable tonnage does not have a serious effect of the estimated probabilities.

**Table 9: Test Statistics for LM-Test: Type I and II models**

| Type of Model | Variable Tested | LM-Statistic | p-value |
|---|---|---|---|
| 6m very serious (type I) | Age | 4.261 | 0.0389 – *do not reject* $h_o$ |
|  | Tonnage | 4.061 | 0.0438 – *do not reject* $h_o$ |
| Combined model (type II) | Age | 5.900 | 0.0268 – *do not reject* $h_o$ |
|  | Tonnage | 20.998 | 0.0000 - *reject* $h_o$ |

*Note: 1% significance level used*

The results for the type III models are shown in Table 10 where no presence of heteroscedasticity could be identified for the variables in question. The remaining statistics of the final models for type I and type II are then presented in Table 11 and for the type III models in Table 12. The table lists the number of observations in each model, the number of twin outliers that were identified and eliminated, the cut off rate and a summary of other relevant statistics.

One cannot see any major difference between probit and logit. The models were reduced using a 1% significance level. Only two variables (deficiency codes) in the less serious casualty model are left in the model at a 5 % significance level. The results are acceptable for the amount of observations in each model. For the type I models, the hit rate and the

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[27] Davidson and McKinnon (1993), *Estimation and Inference in Econometrics*, New York: Oxford University Press, 1993, page 526ff

[28] Knapp, S. (2006), The Econometrics of Maritime Safety – Recommendations to Enhance Safety at Sea, Doctoral Thesis (to be published), Econometric Institute, Erasmus University, Rotterdam

[29] Greene H.W. (2000), *Econometric Analysis, Fourth Edition*, Econometric Analysis, Prentice Hall, New Jersey; page 518ff; Furthermore, recognition is to be given to *Richard Paap* from the Econometric Institute for pointing this program out to me and for making it available to me.

McFadden $R^2$ is higher for the very serious models compared to the other two model types and the HL-statistic indicates a better fit. Logit models are used for the visualization part.

**Table 10: Test Statistics for LM-Test: Type III models**

| **Model** | **Variable Tested** | **LM-Statistic** | **p-value** |
|---|---|---|---|
| Fire/Explosion | Age | n/a | n/a |
| | Tonnage | 1.255 | 0.2625 - *do not reject* $h_o$ |
| Wrecked/Stranded/Grounded | Age | 0.279 | 0.5967 - *do not reject* $h_o$ |
| | Tonnage | 0.398 | 0.5276 - *do not reject* $h_o$ |
| Collision/Contact | Age | 1.019 | 0.3126 - *do not reject* $h_o$ |
| | Tonnage | 2.448 | 0.1176 - *do not reject* $h_o$ |
| Deck Related First Events | Age | 0.194 | 0.6600 - *do not reject* $h_o$ |
| | Tonnage | 0.302 | 0.5823 - *do not reject* $h_o$ |
| Engine Related First Events | Age | 0.176 | 0.6744 - *do not reject* $h_o$ |
| | Tonnage | 0.261 | 0.6091 - *do not reject* $h_o$ |

*Note: 1% significance level was used*

**Table 11: Summary of Statistics – Type I and II Model**

| | **6 months Time Frame** | | | | | |
|---|---|---|---|---|---|---|
| **Type I Models** | **very serious** | | **serious** | | **less serious** | |
| **# observations in final model** | 0 = | 5665 | 0 = | 44124 | 0 = | 26551 |
| | 1 = | 161 | 1 = | 1362 | 1 = | 860 |
| | Total = | 5826 | Total = | 45486 | Total = | 27411 |
| **# outliers (twins)** | none | | none | | none | |
| **Cut Off** | 0.0276 | | 0.0299 | | 0.0314 | |
| | **LOG** | **PRO** | **LOG** | **PRO** | **LOG** | **PRO** |
| **Mc Fadden R2** | 0.166 | 0.162 | 0.139 | 0.139 | 0.077 | 0.077 |
| **% Hit Rate y=0** | 73.93 | 72.22 | 70.00 | 68.28 | 66.95 | 66.00 |
| **% Hit Rate y=1** | 71.43 | 72.67 | 73.35 | 75.18 | 64.07 | 65.23 |
| **% Hit Rate Tot** | 73.86 | 72.23 | 70.10 | 68.49 | 66.86 | 65.97 |
| **HL-Stat. (df=8)** | 9.41 | 19.54 | 3.00 | 16.60 | 9.75 | 9.62 |
| **p-value** | 0.3088 | 0.0120 | 0.9343 | 0.0345 | 0.2832 | 0.2927 |
| **Remarks** | w/o passenger vessels and Caribbean MoU | | with passenger vessels but without Caribbean MoU | | | |

| **Type II Model (VS and Serious)** | | |
|---|---|---|
| **# observations in final model** | 0 = | 50610 |
| | 1 = | 1540 |
| | Total = | 52150 |
| **# outliers (twins)** | none | |
| **Cut Off** | 0.0295 | |
| | **LOG** | **PRO** |
| **Mc Fadden R2** | 0.130 | 0.1292 |
| **% Hit Rate y=0** | 68.88 | 67.09 |
| **% Hit Rate y=1** | 72.53 | 74.09 |
| **% Hit Rate Tot** | 68.98 | 67.29 |
| **HL-Stat. (df=8)** | 11.749 | 24.39 |
| **p-value** | 0.1633 | 0.0020 |

Table 12: Summary of Statistics – Type III Models

| 6 months Time Frame | | | | | | |
|---|---|---|---|---|---|---|
| | **Fire/Explosion** | | **Wrecked/ Stranded/Grounded** | | **Collision/Contact** | |
| **# observations in final model** | 0 = | 5484 | 0 = | 18098 | 0 = | 21641 |
| | 1 = | 191 | 1 = | 502 | 1 = | 688 |
| | Total = | 5675 | Total = | 18600 | Total = | 22329 |
| **# outliers (twins)** | none | | none | | none | |
| **Cut Off** | 0.0337 | | 0.02698 | | 0.0308 | |
| | **LOG** | **PRO** | **LOG** | **PRO** | **LOG** | **PRO** |
| **Mc Fadden R2** | 0.088 | 0.088 | 0.070 | 0.0698 | 0.068 | 0.068 |
| **% Hit Rate y=0** | 66.63 | 65.24 | 67.05 | 66.07 | 67.89 | 66.74 |
| **% Hit Rate y=1** | 66.49 | 67.54 | 64.34 | 65.94 | 61.48 | 62.35 |
| **% Hit Rate Tot** | 66.63 | 65.32 | 66.98 | 66.06 | 67.70 | 66.61 |
| **HL-Stat. (df=8)** | 9.08 | 5.00 | 13.78 | 15.28 | 6.72 | 4.74 |
| **p-value** | 0.3360 | 0.7574 | 0.0878 | 0.0539 | 0.5666 | 0.7849 |
| | | | | | | |
| | **Deck Related** | | **Engine Related** | | **Remarks** | |
| **# observations in final model** | 0 = | 7538 | 0 = | 26260 | ***All Models except*** Engine rel. casualties are w/o the Caribbean ***plus:*** Fire: w/o container WSG: w/o passenger and other ST COCO: w/o other ST Deck: w/o passenger and other ST | |
| | 1 = | 233 | 1 = | 819 | | |
| | Total = | 7771 | Total = | 27079 | | |
| **# outliers (twins)** | none | | none | | | |
| **Cut Off** | 0.0300 | | 0.0310 | | | |
| | **LOG** | **PRO** | **LOG** | **PRO** | | |
| **Mc Fadden R2** | 0.079 | 0.079 | 0.084 | 0.085 | | |
| **% Hit Rate y=0** | 65.46 | 64.13 | 69.72 | 68.74 | | |
| **% Hit Rate y=1** | 67.81 | 69.96 | 63.00 | 64.22 | | |
| **% Hit Rate Tot** | 65.53 | 64.30 | 69.52 | 68.60 | | |
| **HL-Stat. (df=8)** | 4.80 | 4.15 | 6.32 | 3.90 | | |
| **p-value** | 0.7789 | 0.8438 | 0.6111 | 0.8664 | | |

*Note: WSG = Wrecked, Stranded, Grounded, COCO = Collision/Contact*

The results of the type III models are not as good as the models based on the seriousness of casualty which is expected to be the case. The results are still acceptable and the hit rate is still above 65% for all models. The models had to be adapted according to the number of observations and for most models (except engine related), the Caribbean MoU had to be taken out as well as the passenger vessels and other ship types due to lack of data. Not much difference can be seen between the logit and the probit models and logit models are used for the visualization part.

### *3.5. Visualization of Refined Results – Effect of Inspections*

Table 13 lists a summary of the coefficients of the variables of interest for the type I, type II and type III series of models. The main findings from this table can be summarized as follows and will be visualized in the sections to come.

## Table 13: Summary of Main Variables and their Significance: All Twin Models

| | | Type I Models | | | Type II Model | | Type III Models | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Variables of Interest** | | **very serious** | **serious** | **less serious** | **combined model very serious & serious** | | **Fire Expl.** | **W/S/G** | **Collision Contact** | **Deck Related** | **Engine Related** |
| ***Industry Inspections*** | | **Coef.** | **Coef.** | **Coef.** | **Coef.** | **Coef 2nd ST** | **Coef.** | **Coef.** | **Coef.** | **Coef.** | **Coef.** |
| | Rightship 1 star (RS inspected) | benchmark | | | benchmark | | n/s | n/s | n/s | -1.4344 | n/s |
| | Rightship 2 star | -1.0013 | -0.9613 | -0.2872 | -0.9796 | | n/a | n/a | n/a | n/a | n/a |
| | Rightship 3 star | -1.3447 | -1.1532 | -0.5105 | -1.1838 | | n/a | n/a | n/a | n/a | n/a |
| | Rightship 4 star | -2.4995 | -2.7490 | -0.5970 | -2.7714 | | n/a | n/a | n/a | n/a | n/a |
| | Rightship 5 star | -3.0056 | -3.9050 | -0.7596 | -3.8793 | | n/a | n/a | n/a | n/a | n/a |
| | Greenaward Certified | n/s | n/s | n/s | n/s | | n/s | n/s | n/s | n/s | n/s |
| ***Port State Control Inspected/Detained*** | | | | | | | | | | | |
| | Time in-between inspections | n/s | 0.1526 | 0.1169 | 0.1107 | | 0.1503 | n/s | n/s | n/s | 0.0938 |
| | Paris MoU inspected | n/s | n/s | n/s | n/s | | n/s | n/s | n/s | n/s | 0.8225 |
| | Caribbean MoU inspected | not in model | | | n/s | | not in model | | | | n/s |
| | Viña del Mar MoU inspected | -1.3812 | -0.6322 | -0.6322 | -0.8266 | | -1.0950 | n/s | -0.9150 | -1.2067 | n/s |
| | Indian Ocean MoU inspected | n/s | -1.5607 | -1.5607 | -1.4198 | | -1.5103 | -1.2964 | -1.1704 | -2.3361 | n/s |
| | USCG inspected | n/s | n/s | n/s | -0.3184 | | n/s | n/s | n/s | n/s | 0.8545 |
| | AMSA inspected | n/s | -0.5662 | -0.5662 | -0.5182 | | n/s | -1.3373 | -0.8534 | n/s | n/s |
| | Paris MoU detained | n/s | n/s | n/s | n/s | | n/s | n/s | n/s | n/s | n/s |
| | Caribbean MoU detained | not in model | | | n/s | | not in model | | | | n/s |
| | Viña del Mar MoU detained | n/s | n/s | n/s | n/s | | n/s | n/s | n/s | n/s | n/s |
| | Indian Ocean MoU detained | n/s | n/s | n/s | n/s | | n/s | n/s | n/s | n/s | n/s |
| | USCG detained | n/s | n/s | n/s | n/s | | n/s | n/s | n/s | n/s | -0.3169 |
| | AMSA detained | n/s | n/s | 0.7553 | n/s | | n/s | 0.6844 | n/s | n/s | 0.5202 |
| ***Deficiencies Found (only significant ones are listed)*** | | | | | ***per ship type*** | | | | | | |
| C0400 | Food and catering | n/s | n/a | n/s | -0.6149 (ST3) | | n/s | n/s | n/s | n/s | -0.1245 |
| C0500 | Working spaces & acc.prev. | n/s | n/s | n/s | n/s | | n/s | n/s | n/s | n/s | n/s |
| C0700 | Fire Safety measures | n/s | 0.0335 | n/s | 0.0495 (ST1) | | n/s | 0.02376 | n/s | n/s | 0.0432 |
| C0900 | Structural Safety | n/s | n/s | 0.0252 | 0.0657 (ST3) | | n/s | n/s | 0.0315 | n/s | n/s |
| C1000 | Alarm Signals | n/s | n/s | n/s | n/s | | n/s | 0.2636 | n/s | n/s | n/s |
| C1200 | Load lines | n/s | n/s | n/s | -0.0527 (ST1) | 0.1261 (ST4) | n/s | n/s | n/s | 0.0701 | n/s |
| C1400 | Propulsion & aux.engine | n/s | 0.0318 | 0.0241 | 0.0467 (ST2) | | 0.0486 | 0.02231 | n/s | n/s | 0.0645 |
| C1700 | MARPOL A. I (Oil Pollution) | n/s | n/s | 0.0573 | n/s | | n/s | n/s | n/s | n/s | 0.0449 |
| C1800 | Gas and chemical carriers | 0.5037 | n/s | n/s | n/s | | 0.2849 | n/s | n/s | n/s | n/s |
| C1900 | MARPOL A.II (Noxious L.) | n/s | n/s | n/s | n/s | | n/s | n/s | n/s | 0.5146 | n/s |
| C2000 | SOLAS Operational def. | n/s | -0.0724 | n/s | -0.1117 (ST1) | | n/s | n/s | n/s | n/s | -0.0801 |
| C2100 | MARPOL relat. oper. def. | n/s | n/s | n/s | n/s | | n/s | n/s | -0.3094 | n/s | n/s |
| C2200 | MARPOL A.III | n/s | n/s | n/s | n/s | | n/s | n/s | n/s | n/s | n/s |
| C2300 | MARPOL A.V | n/s | n/s | -0.1578 | n/s | | n/s | n/s | n/s | n/s | n/s |
| C2500 | ISM related deficiencies | n/s | 0.0392 | n/s | 0.04147 (ST1) | 0.1193 (ST4) | n/s | n/s | 0.0624 | n/s | n/s |

*Note: n/s= not significant, n/a=not applicable, W/S/G=Wrecked, Stranded, Grounded; ST1=general cargo, ST2=dry bulk, ST3=container, ST4=tanker, ST5=passenger*

***Overall Summary***

- The coefficients for the variables indicating if a ship has been inspected by one of the *industry vetting inspection regimes* (Rightship) for bulk carriers and oil tankers are all negative and follow the overall ranking of a vessel[30] while the coefficient of the variable indicating if the ship is Greenaward certified is not significant which might be just due to lack of data[31]. For the type III models, this parameter is only significant for deck related first events. Given the fact that those inspections are primarily carried out on bulk carriers, this finding is found to be in line with the general expectation.
- *The parameter of the variable indicating time in-between inspections* is not significant for very serious casualties but is positive for all other categories of the type I and type II models. For the casualty first events, it is only significant for fire & explosion and engine related first events.
- The coefficients of the variables indicating where the ship was inspected is mostly negative for serious and less serious casualties and only one regime remains significant for very serious casualties (Viña del Mar Agreement on PSC). For the casualty first events, these parameters are mostly negative or not significant with the exception for engine related first events where it is positive for two regimes.
- The coefficients of the variables indicating if the ship was detained are mostly not significant with the exception of less serious casualties and for the categories wrecked, stranded or grounded and engine related first events. For engine related first events, the parameter is negative for one regime (USCG).

***Deficiencies per seriousness and ship type (type I and II models)***

- For *very serious casualties*, a positive effect can be found with code 1800 (gas and chemical carriers) and not other code remains significant.
- For *serious casualties*, a negative effect can be found for codes 2000 (SOLAS operational deficiencies) while a positive effect can be seen with codes 700 (fire safety measures), codes 1400 (propulsion and aux. engine) and code 2500 (ISM code).
- For *less serious casualties*, only one code shows a negative effect – code 2300 (Marpol Annex V). Codes with positive effect are code 900 (structural safety), code 1400 (propulsion and aux. engines) and code 1700 (Marpol Annex I).
- With respect to the *deficiencies per ship type* (type II model), codes that remain significant for general cargo vessels are code 700 (fire safety measures: positive), code 1200 (load line: negative), code 2000 (SOLAS oper. safety: negative) and code 2500 (ISM related def.: positive).
- For dry bulk, only one code remains significant and positive which is code 1400 (propulsion and aux. engine). For the container vessel, codes 400 (food and catering: negative), code 900 (structural safety: positive) remain significant. For tankers, two codes remain in the model and are code 1200 (load lines: positive) and code 2500 (ISM related deficiencies: positive).

***Deficiencies per casualty first event (type III models)***

- Looking at the deficiency codes and the significance of their parameters with respect to the casualty first events, for *fire and explosion,* codes 1400 (propulsion and aux. engines) and code 1800 (gas and chemical carriers) are significant and positive.

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[30] For Rightship, the risk associated with a vessel is ranked by stars where a 1 star vessel shows highest risk and a 5 star vessel shows lowest risk

[31] the total amount of Greenaward certified vessels incorporated into the dataset was only about 240 records for the time span 2000 to 2004

- For the category *wrecked/stranded/grounded*, the remaining codes are code 700 (fire safety measures), code 1000 (alarm signals) and code 1400 (propulsion and aux. engines) are significant and positive[32].
- For *collision/contact,* two codes are positive as – code 900 (structural safety) and code 2500 (ISM related def.) and one codes is negative – code 2100 (Marpol relat. operat. deficiencies).
- For *deck related first events*, codes 1200 (load lines) and code 1900 (Marpol Annex II) are significant and positive.
- For *engine related first events*, four codes remain of which three are positive and two are negative. Positive effects are with codes 700 (fire safety measures), 1400 (propulsion and aux. engines) and 1700 (Marpol Annex I) while negative effects are with codes 400 (food and catering) and code 2000 (Solas operat. deficiencies).

***Summary of Findings in relation to deficiencies***

It is difficult to interpret the significance and the sign of the parameters of the deficiency codes towards either the seriousness and with respect to the ship types or the casualty first events since the variable is not based on the last inspection only but also contains information from previous inspections. Sometimes, this means an accumulation of inspections and sometimes this means, only the last inspection which was performed at least six months or less before the casualty. The analysis is therefore only being seen as a first attempt to look at both aspects closer.

What can be concluded from this portion of the analysis is that some inspections and the fact that deficiencies are found are effective towards decreasing the probability of having a casualty. This effect varies across ship types, seriousness of casualty and casualty first events. Code 1400 (propulsion & aux. engine) seems to be an important deficiency code which in the probability of detention does not come out to be very important in all regimes. It has a positive effect for serious and less serious casualties, in particular for dry bulk carriers and for casualty first events such as fire & explosion, wrecked/stranded/grounded and engine related casualty first events. This could indicate that there is room for improvement. It seems that deficiencies are found but due to lack of enforcement (detention) or follow up on deficiencies, the effect is positive rather than negative. It is important to notice though that when the vessel is in port and port state control is performed, the engines are not under full operation and it is therefore difficult to inspect some aspects of the main engine.

Another code where its parameter shows a positive effect is the ISM code (code 2500) which captures the whole safety management system onboard a vessel. It is positive for serious casualties, general cargo vessels and tankers and for casualty first event collision and contact. On the other hand, code 2000 (Solas operational related deficiencies) is negative for serious casualties and engine related first events for the ship type general cargo. This could be interpreted as the effectiveness in rectifying the deficiencies or drills and therefore having a negative effect for general cargo ships.

Another clear example is code 1800 (gas and chemical carriers) which is positive and significant for very serious casualties and casualty first events fire and explosion. This could be further identified as an area that should be looked at and has already been discussed at IMO during MSC (81) in May 2006[33]. This finding confirms that there is problem with enforcing the legal conventions on chemical carriers. The next area will

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[32] code 700 and code 1400 are significant at the 5% level only

[33] The author attended as observer MSC (81) in May 2006, IMO, London

present some graphs to visualize the findings. It will first look at the time in-between inspections, the effect of inspections and detention and the deficiencies themselves.

Table 14 is based on the type I models where restrictions[34] using the Wald Test were tested for the variables indicating where the vessel was inspected to see if the means differ. The null hypothesis in this case states that there is no significant difference across the regimes ($h_o$= *coefficients do not vary*). The results indicate that while there is no significant difference with relation to very serious casualties (only one variable remains significant), for serious casualties, AMSA and the Viña del Mar MoU are apart from the IMOU. No difference can be seen for the Paris MoU and the USCG since as a benchmark, the Paris MoU was used and the USCG does not remain to be significant.

**Table 14: Testing of Restrictions (Wald Test) - Inspection Variables: Type I Models**

| Very Serious | Serious Restrictions/p-value | Less Serious Restrictions/p-value |
|---|---|---|
| Only the VMOU remains significant and shows a negative effect. There is no significant difference amongst the other regimes. | AMSA=IMOU=VMOU<br>(0.0017) – *reject $h_o$* | AMSA=IMOU=VMOU<br>(0.0286) - *do not reject $h_o$* |
| | AMSA=IMOU<br>(0.0007)- *reject $h_o$* | AMSA=IMOU<br>(0.1054)- *do not reject $h_o$* |
| | IMOU=VMOU<br>(0.0013) - *reject $h_o$* | IMOU=VMOU<br>(0.0086)- *reject $h_o$* |
| | AMSA=VMOU<br>(0.07607) – *do not reject $h_o$* | AMSA=VMOU<br>(0.2040) - *do not reject $h_o$* |

*Note: Figure in bracket is the p-value of the test, 1% significance level*

For less serious casualties, AMSA, the Indian Ocean MoU and the Viña del Mar Agreement do not show a difference (at the 1% significance level) while the USCG and the Paris MoU are not significant. Figure 10 to Figure 12 both visualize these effects for a particular ship for a particular vessel but not in a combined format. The variables indicating where a ship was inspected is constructed as a percentage fraction of each vessel to the total inspection a vessel had previously and not as a total sum of inspections which was used in the normal casualty models. What the variables give is a capture of the total inspection fraction of all of the regimes of a particular vessel where the Caribbean MoU had to be excluded from the models due to lack of data.

In order to visualize the differences, a particular ship is chosen and its associated probability of casualty is calculated. In order to see the effect over time, the variable in question is increased by certain percentage fractions (10%) which can also be seen as an increase in the frequency of inspections. The interesting part in these graphs is to see how the regimes differ with respect to the probability of casualty. As mentioned before, only the Viña del Mar Agreement on PSC is significantly different from the other regimes for very serious casualties. The average is to be understood as the average of all regimes.

For serious casualties, AMSA and the Indian Ocean MoU are very close and apart from the Indian Ocean MoU and the other regimes. For less serious casualties, AMSA, the Indian Ocean MoU and the Viña del Mar Agreement on PSC are similar (also confirmed previously) and below the average. They are different from the Paris MoU and the USCG.

At first sight, the order of the regimes is not as one would have expected them to be. Regimes below the average seem to show a larger effect. On the other hand, it might also

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[34] based on Wald Test for Testing Coefficient Restrictions, a standard procedure in Eviews

reflect the learning stage of a regime over the time period covered by the inspection data. By the end of 2004, the Paris MoU has been in existence since 1982 while the Indian Ocean MoU only exists since 7 years and the Viña del Mar since 13 years.

Figure 10: Inspection Effect across Regimes: Very Serious

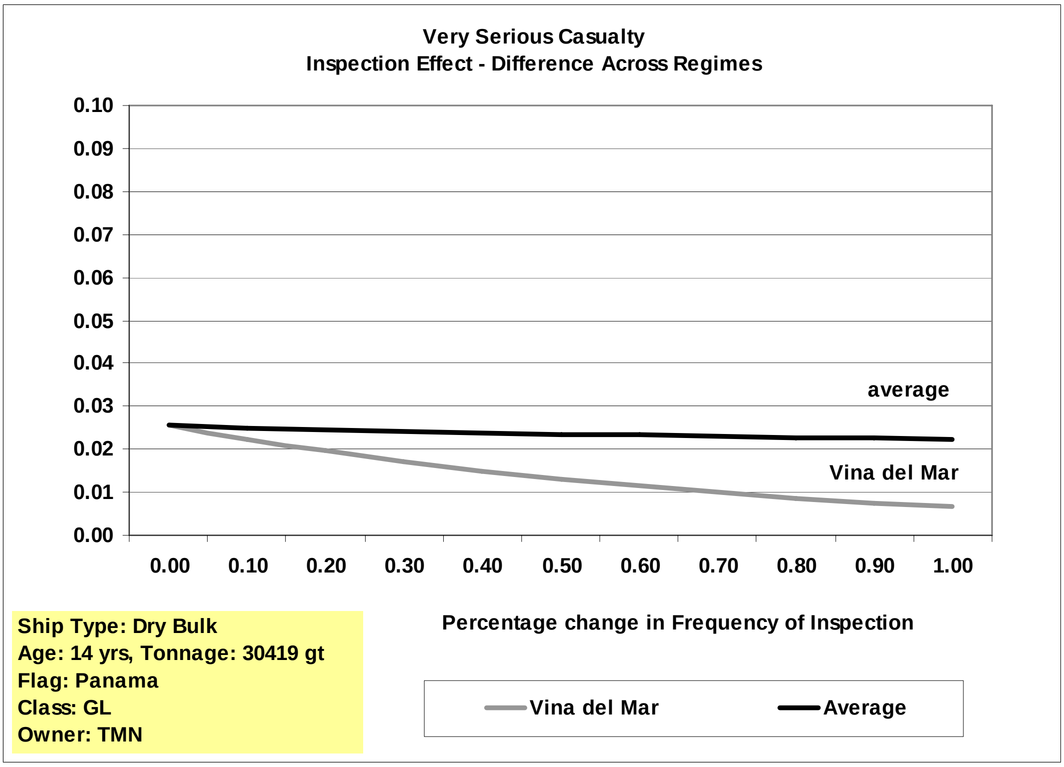


Figure 11: Inspection Effect across Regimes: Serious

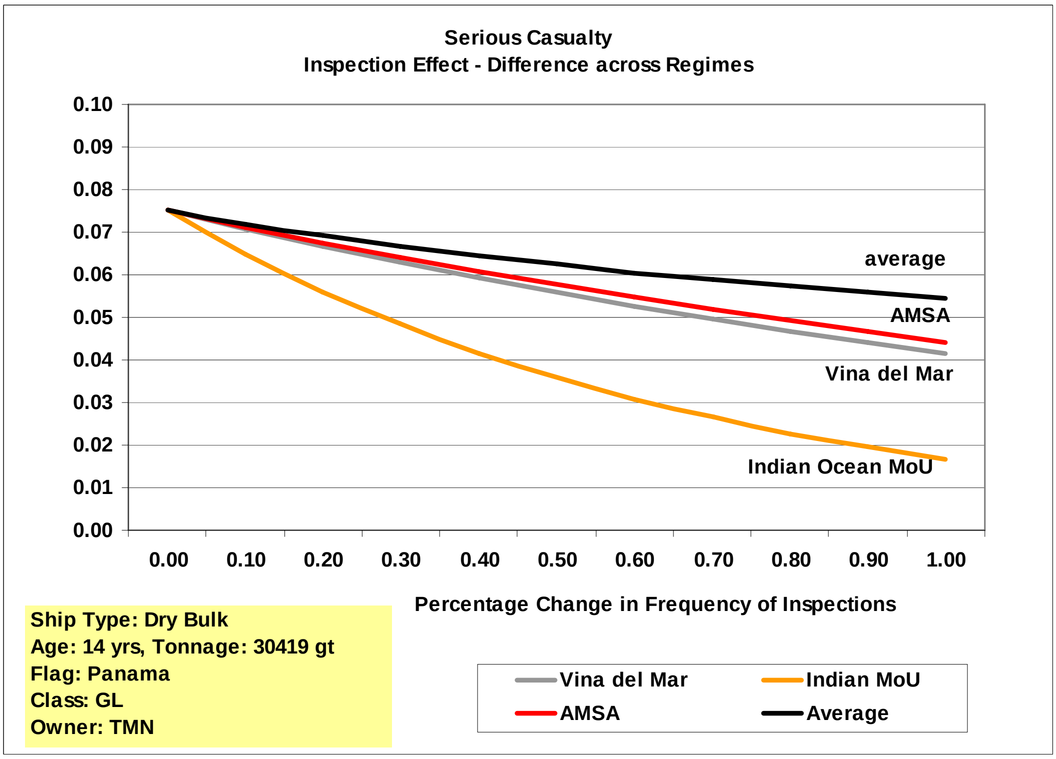
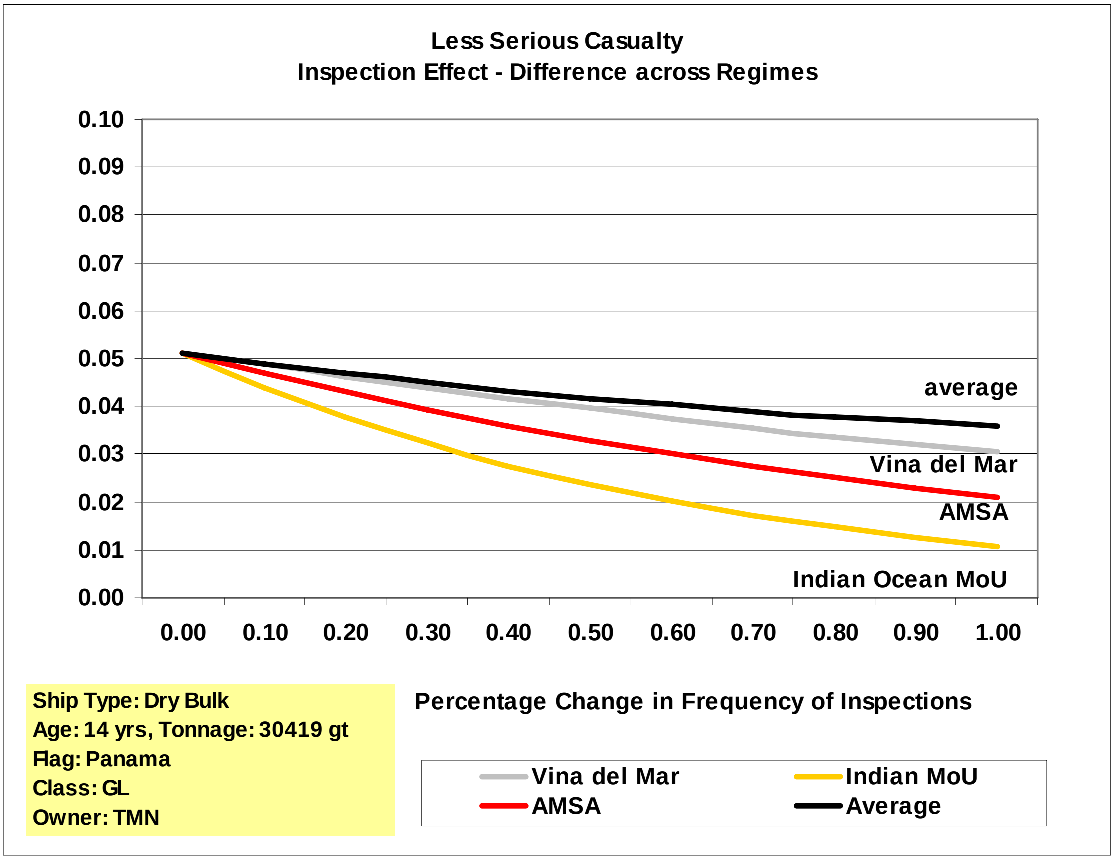


**Figure 12: Inspection Effect across Regimes: Less Serious**



The Indian Ocean MoU region has more local trade with ships that might show more obvious signs of being sub-standard and the effect of inspections are therefore to be expected to be higher than in other regions with better ships. In addition, the Paris MoU area has maintained the 25% target factor previously which could have led to the inspection of good ships in the past in order to fill the quota versus sub-standard ships when they have not been available in the area needed for inspection for the last six years. As for the Viña del Mar region, the region might show more of the sub-standard ships that have been driven out of the Paris MoU or the USCG over the last six years.

The next section will give an overview in relation to the casualty first events based on the type III models and similar to the procedure described for the type II models. The results can be seen in Table 15.

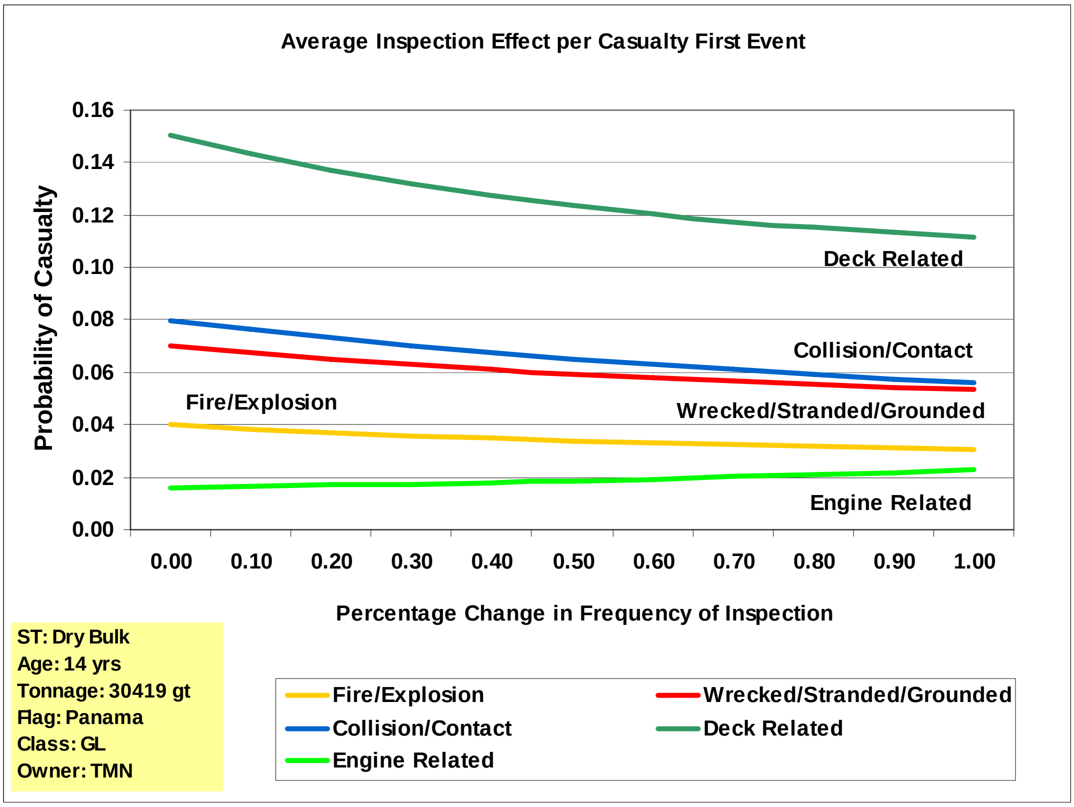
**Table 15: Testing of Restrictions (Wald Test) - Inspection Variables: Type III Models**

| Model Type | Variables Tested | p-value |
|---|---|---|
| Fire/Explosion | VMOU=IMOU | 0.5819 - *do not reject* $h_o$ |
| Wrecked/Stranded/Grounded | AMSA=IMOU | 0.9359 - *do not reject* $h_o$ |
| Collision/Contact | AMSA=VMOU=IMOU | 0.7131 - *do not reject* $h_o$ |
| Deck Related First Events | VMOU=IMOU | 0.1136 - *do not reject* $h_o$ |
| Engine Related First Events | USCG=PMOU | 0.0406 - *do not reject* $h_o$ |

*Note: 1% significance level used*

One can see that there are no significant differences for the variables that are left in the models across the regimes and that the null hypothesis ($h_o$= *coefficients do not vary)* can be rejected in all cases at a 1% significance level. The results are visualized with a combined graph (Figure 13) which shows the average effect of inspection on the probability of casualty per first event for a dry bulk carrier. The average is based on an average of all regimes and is therefore more averaged out in comparison to each of the individual variables.

**Figure 13: Average Inspection Effect per Casualty First Event**



The graph shows that the strongest effect can be seen for deck related first events followed by collision/contact similar to the category wrecked/stranded/grounded and fire/explosion. For engine related first events, the effect is slightly positive. Linking this graph back to the probability of detention and deficiency code 1400 (propulsion and aux. machinery) where the contribution weight of this code was found not to be very high across all regimes, one could conclude that there is room for improvement in this area.

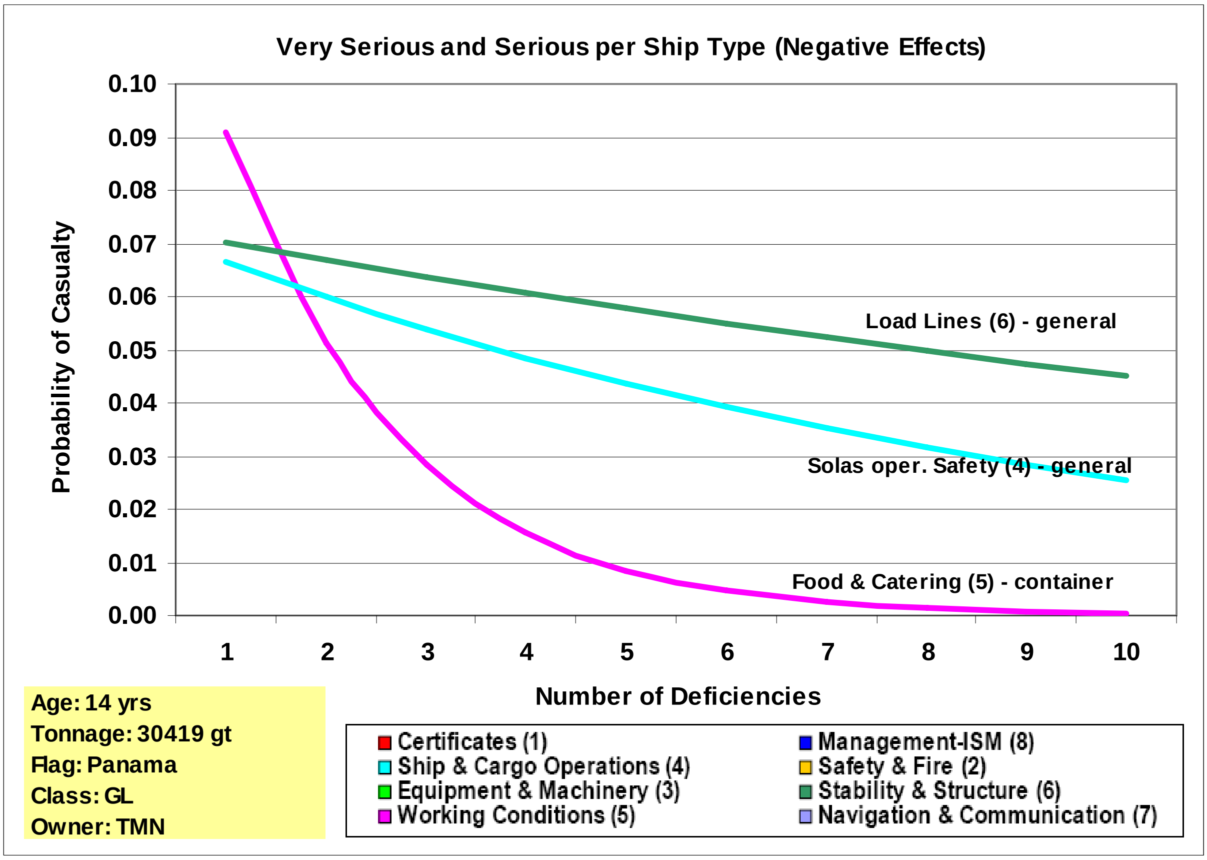
### *3.6. PSC Deficiencies and the Probability of Casualty*

The next area will provide a closer look at deficiencies in relation to seriousness and first events of a casualty and is based on the type I, type II and type III models. It visualizes the findings stated in Table 13 previously in order to facilitate the interpretation of the coefficients.

The first set of graphs are based on the type II model (the combined model) where the deficiencies are multiplicative dummy variables of the ship types and combine very serious and serious casualties. Figure 14 and Figure 15 show the results for codes with negative effects and codes with positive effects.

The negative effect of food and catering for container vessels cannot really be explained other than that an improvement in working and living conditions for crew members onboard have an overall positive effect on the performance of the crew.

**Figure 14: Very Serious and Serious Casualties (Negative Effects)**



*Note: based on type II models*

The significance of the other two codes for general cargo ships are easier to interpret. According to the Paris MoU Manual for PSC Officers[35] deficiencies in the area of load lines include overloading, freeboard markings, conditions of railings, cargo hatches, doors, ventilation pipes and lashings. It seems that general cargo vessel seems to show deficiencies in this area prior to a casualty and that these deficiencies are rectified. For load line, rectification might not be so easy and immediate while for deficiencies in the area of SOLAS related deficiencies, it can be rectified easier and therefore have an immediate effect. SOLAS related operational deficiencies include deficiencies such as the muster list, fire drills, abandon ship drills, the level of communication onboard, bridge operations, the operation of GMDSS and cargo operations. It shows that if port state control identifies these deficiencies and if they are rectified, they can have a negative effect. In addition, the drills might help in this respect to. The only regime who requires drills during an annual exam is the USCG.

Figure 15 shows the deficiency codes that have a positive effect towards the probability of casualty. ISM appears twice (for tankers and general cargo) and codes associated with stability and structure (load lines and structural safety) are relevant for containers and tankers. It might be more difficult to rectify deficiencies in this area since it might take more time to do so. In the case of lack of follow up, it seems that ships with deficiencies in this area show a higher probability of having a very serious or serious casualty.

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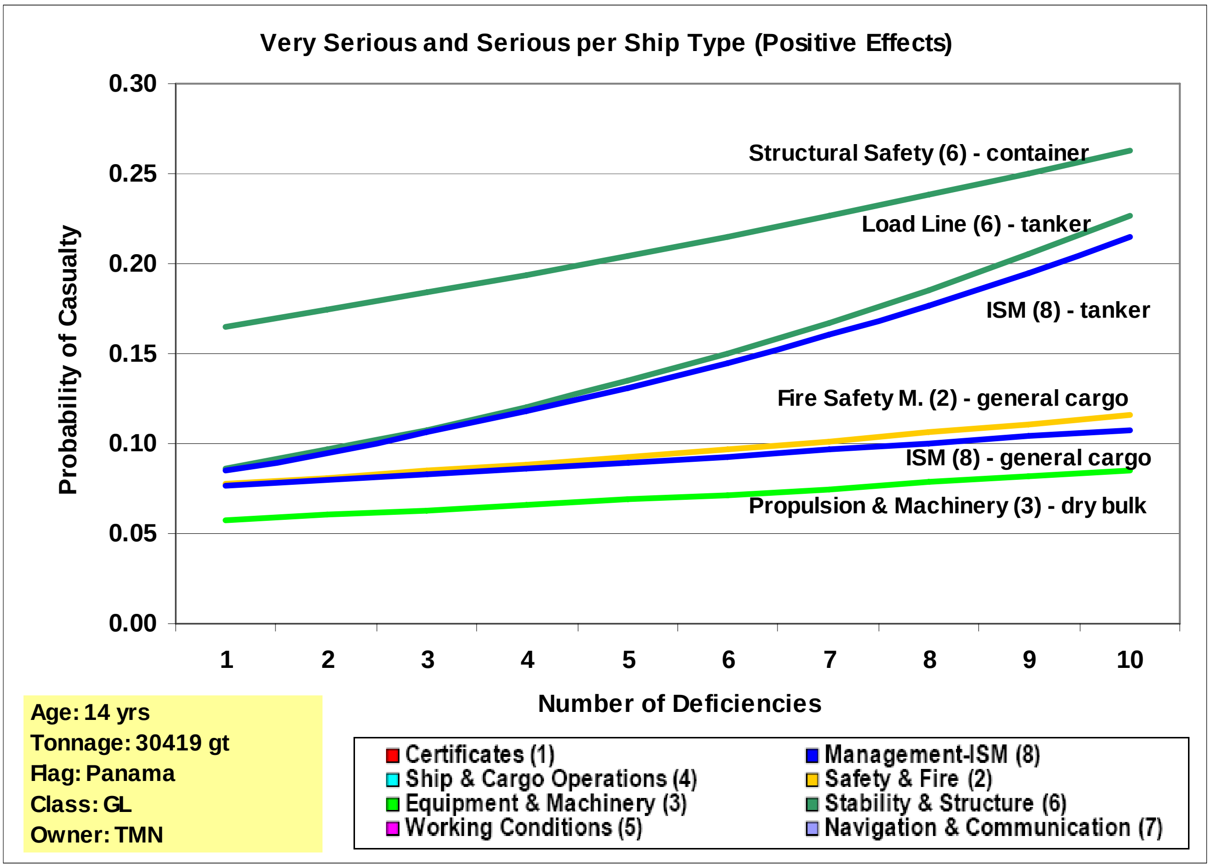
[35] Paris MoU, Manual for PSC Officers, Revision 8

**Figure 15: Very Serious and Serious Casualties (Positive Effects)**



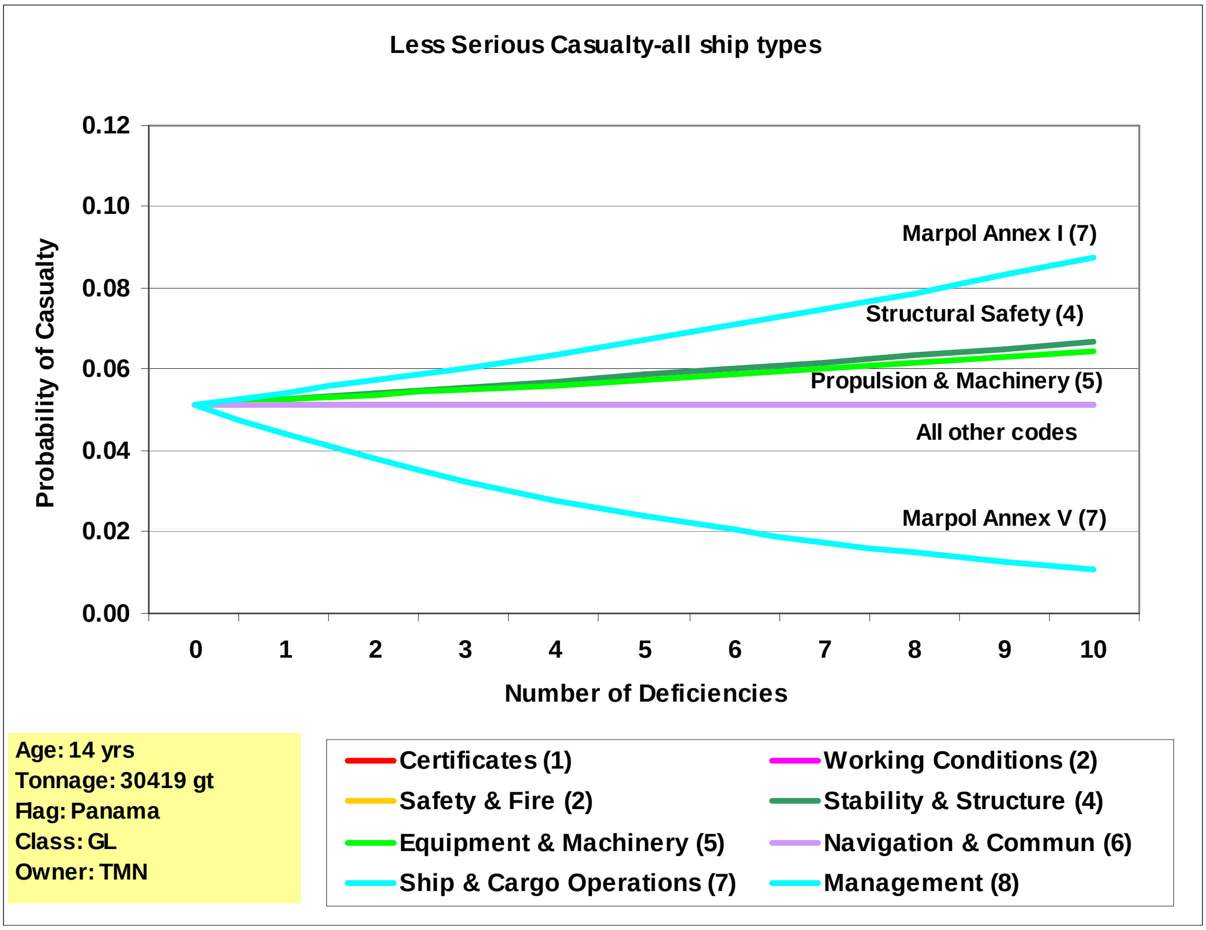
*Note: based on type II models*

Fire safety measures are relevant for general cargo and show that general cargo ships might show more problems with the actual equipment related to fire prevention while the drills and the performance of drills reflects the operational side which can have a negative effect. Very little effect can be seen by deficiencies in the area of propulsion and machinery for dry bulk vessels.

What is not visualized here but clearly shown in Table 13 is the positive effect of code 1800 (gas and chemical carriers) towards the probability of a very serious casualty. This code is associated with deficiencies in the area of cargo segregation, cargo transfers and ventilation systems, the cargo pump room, temperature controls, and fire protection of cargo deck areas, personal protection and emergency towing arrangements. It applies to chemical tankers, gas carrier and oil tankers and shows that this is an area port state control can improve in not only detecting the deficiencies but also in ensuring that they are rectified and that the ISM system onboard is implemented onboard which is further confirmed by the positive effect of the ISM code with tankers. This is somehow surprisingly given the fact that tankers undergo a significant amount of vetting inspections which also looks closely at the implementation of the ISM code.

Figure 16 shows the deficiency codes which are left to be significant for less serious casualties for all ship types. It is less accurate than the previous models but confirms two areas – structural safety and propulsion and machinery with a moderate positive effect and Marpol Annex I (oil pollution) with a stronger positive effect.

**Figure 16: Less Serious Casualties and Deficiencies**



*Note: based on type I model – less serious*

Deficiencies in this area contain for instance the SOPEP (Ship oil emergency plan), the oil record book, the 15 ppm alarm and oil filtering equipment, the segregation of ballast tanks, the operation of COW (crude oil washing). The probability of detention is very strong in this area for the USCG especially for tankers but in aggregated form, for all ship types (contribution weight is about 21%), this code is not significant for very serious or less serious casualties but might play a role for less serious casualties and could be an area of potential problems.

This last section takes a closer look at the various types of casualties and the deficiencies that were found during an inspection. A separate graph per casualty first event is produced and is shown in Figure 17 through Figure 21.

Figure 17 shows the results for fire and explosion identified as first event. Fire and explosion in this case means a fire and explosion anywhere on the vessel where the main area of fire has been identified to be in the engine room. Code 1800 (oil, chemical tankers and gas carriers) and code 1400 (propulsion and machinery) both show a positive effect towards the probability of having a fire or explosion. This finding is interesting as it confirms a problem that is already known in the industry and which has been an agenda item during MSC[36] (81) in May 2006 where a study conducted by an inter-industry workgroup identified 35 cases of fire and explosions on chemical and product tankers over the last 25 years.

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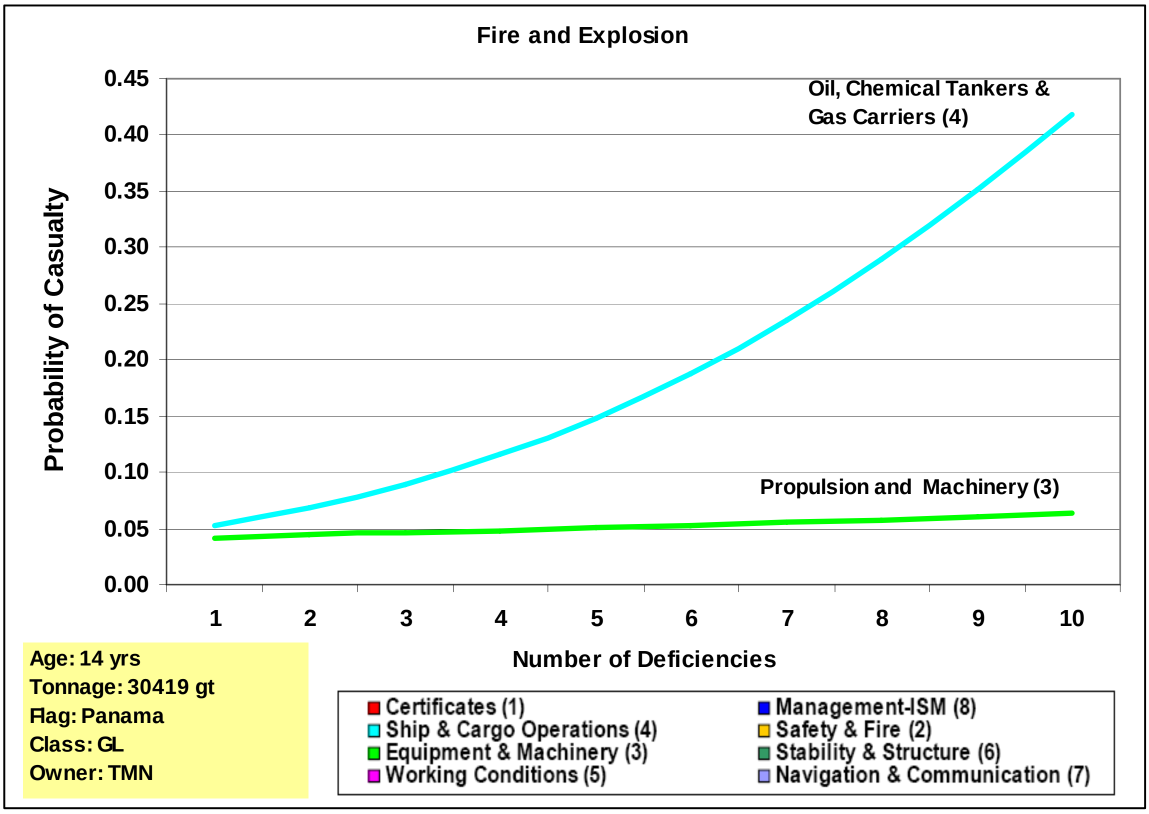
[36] Maritime Safety Committee Meeting at IMO (10th to 19th May 2006)

Figure 17: Fire and Explosion and Deficiencies



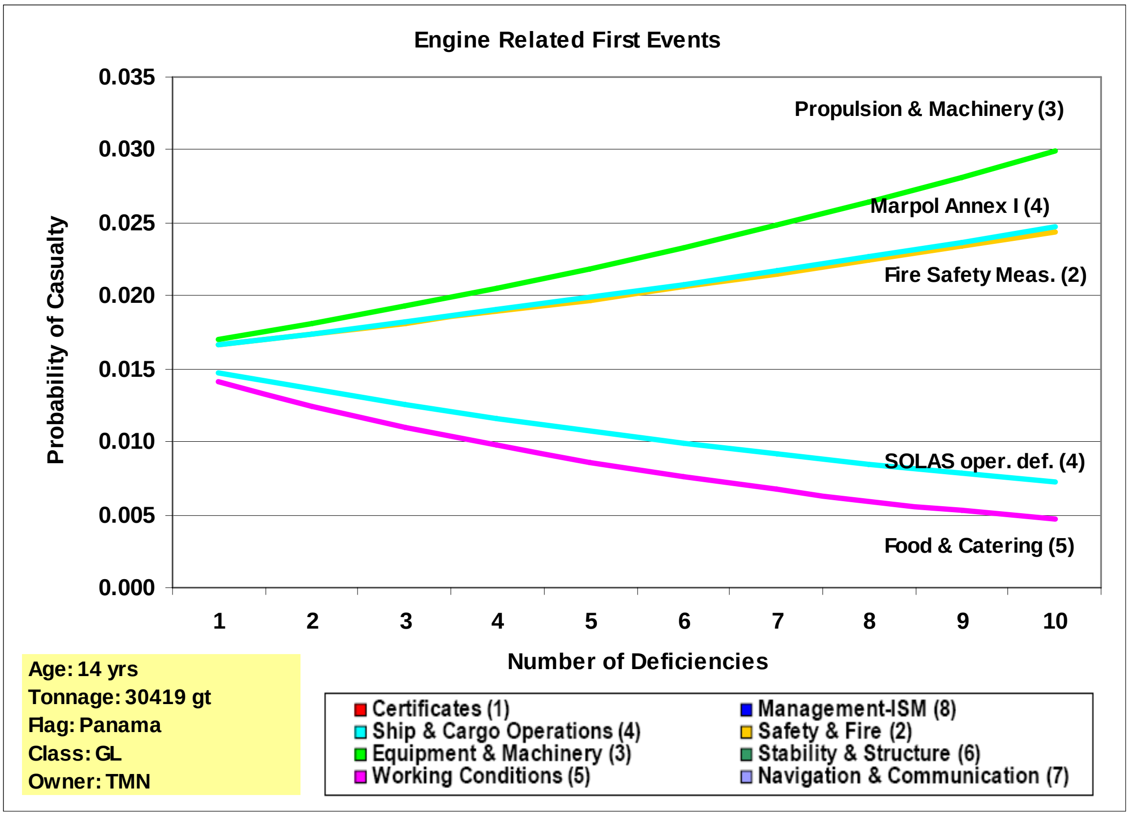
*Note: based on type III model*

The group concluded that technical failure could not be identified but that the prime contributor was lack of following the proper operational guidelines which is partly reflected in the ISM system (onboard and shore side) and might also explain the positive contribution of the ISM code for tankers in Figure 15. From the port state control point of view, it shows that a certain lack of compliance has been detected but that the system lacks in enforcement and implementation. The same applies to propulsion and machinery where the effect is much less.

Figure 18 shows the probability of engine related first events and Figure 19 gives an insight into the probability of deck related first events in relation to deficiencies previously found in port state control inspections.

Engine related first events contain engine breakdowns, black outs, steering gear failure and propulsion failure. It is therefore not surprising that deficiencies associated with code 1400 (Propulsion and machinery) shows the strongest positive contribution followed by Marpol Annex I (code 1700) and fire safety measures (code 700). Marpol Annex I has also been identified with a positive effect for less serious casualties which might also be reflected here. The code is not unrelated to the engine room but somehow not directly related to the events listed above since it deals with environmental issues (oil pollution) and all procedures connected to it. The fact that this code is positive can also just indicate the lack of the implementation of operational procedures in the engine room and that ships that do have a high probability of engine related casualties, also do have a problem in the area of pollution prevention and fire & safety measures.

**Figure 18: Engine Related First Events and Deficiencies**



*Note: based on type III model*

On the other hand, two codes show a negative effect which are code 2000 (SOLAS operational related deficiencies) and code 400 (food and catering). Both codes also show a negative effect for very serious and serious casualties for general cargo ships and container vessels. It seems that drills and other operational related items do have a negative effect on the probability of having an engine related casualty. The code food and catering might just reflect the human factor such as living and working conditions in general which are also associated with food.

Figure 19 shows the probability of deck related first events and two deficiency codes which remain significant – Marpol Annex II (code 1900) and load lines (code 1200). Deck related first events contain items such as deck maintenance and stability related items (capsizing, listing, cargo shifts and flooding).

According to the Paris MoU PSC Manual for PSC Officers[37], deficiencies associated with Marpol Annex II (Noxious Liquids in Bulk) are deficiencies such as the cargo record book, the P&A (Procedure & Arrangement Manual) manual, stripping and tank washing equipment, cargo heating systems and ventilation equipment. At first sight, this code does not seem to be directly associated with deck related first events but by taking a closer look, one can identify a connection, especially when it comes to cargo handling which might also be reflected in deficiencies associated with load lines where cargo shifts or flooding might be more relevant. Interesting to see is that for instance the ISM code is not relevant which is somehow unexpected. Overall, one can conclude that the lack of following proper cargo operation procedures (in what form ever) do have a positive influence on the probability of having a casualty. For port state control, this could mean that deficiencies in this area have

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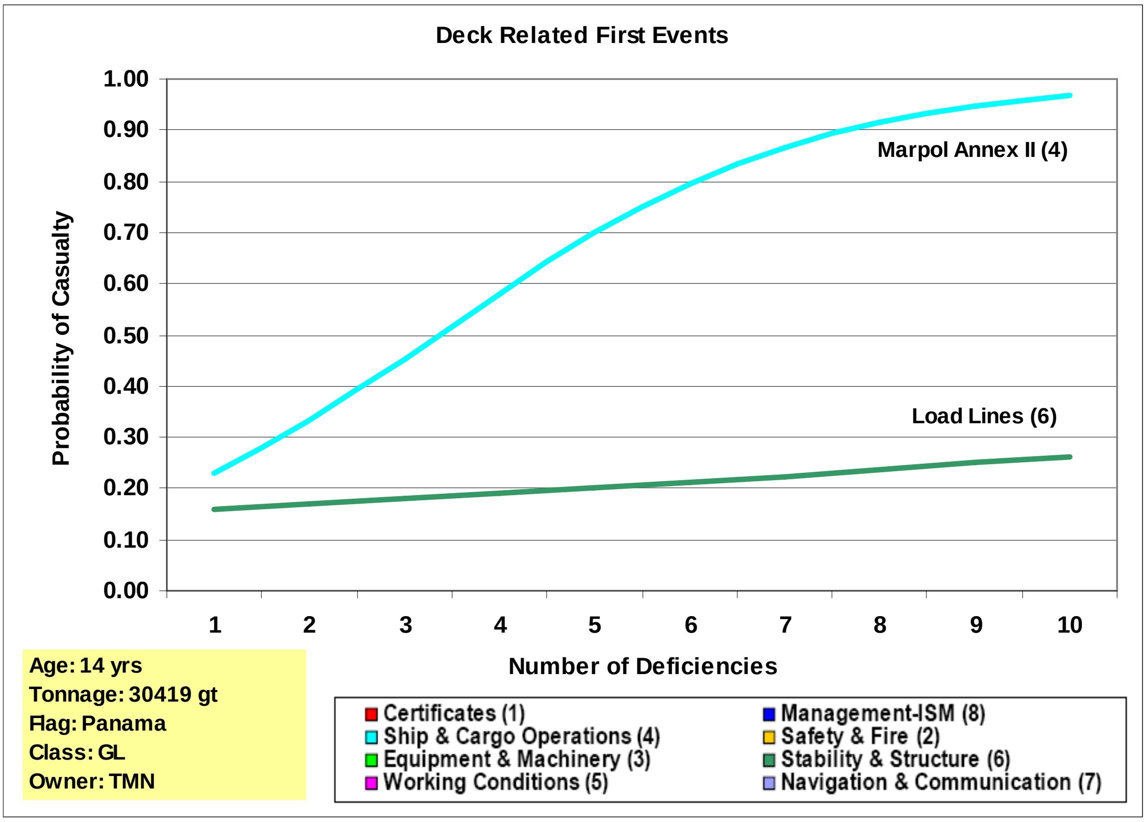
[37] Paris MoU, Manual for PSC Officers, Revision 8

been identified but that there is lack of ability to ensure that these procedures are followed in the future.

**Figure 19: Deck Related First Events and Deficiencies**

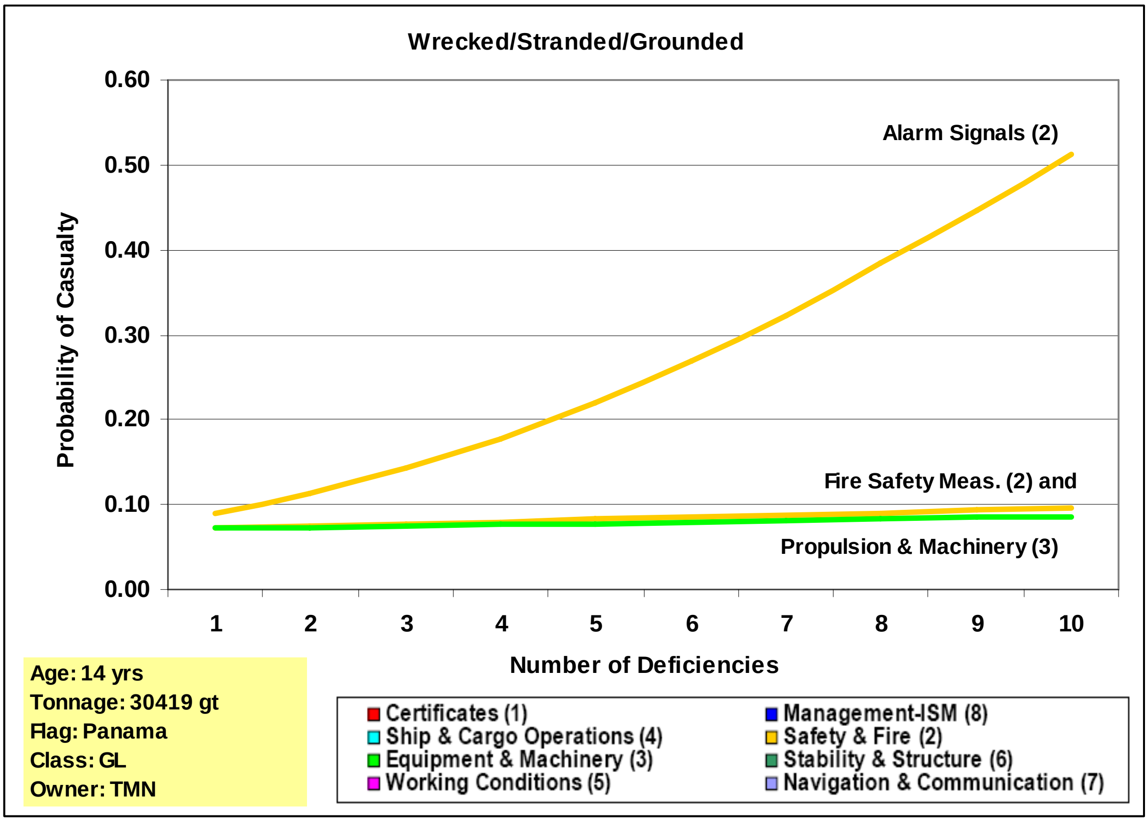


*Note: based on type III model*

Figure 20 shows the effect of deficiencies on casualty first events associated with ships that were wrecked, stranded or grounded. This category is dominated by stranded and grounded ships versus wrecked ships. Three codes are significant and show a positive effect – code 1000 (Alarm Signals), code 700 (fire safety measures) and code 1400 (propulsion and machinery) where the last two are only slightly significant. The more interesting group of deficiencies are the groups of alarm signals which contains deficiencies related to the general alarm, crew and fire alarm, steering gear alarm, engineer's and other machinery alarms, inert gas alarm, UMS (unmanned machinery spaces) and boiler alarms. The types of alarms which can be brought into relation with the first event are probably the alarms associated with the steering gear and other machinery alarm. It seems that deficiencies are identified in this area by port state control and that the positive effect is rather strong.

Figure 21 shows the last graph in this series and shows that deficiencies found in the area of ISM (code 2500) have a positive effect on the probability of having a collision or contact. The same applies for structural safety (code 900). Deficiencies in the 900 range contain closing devices (such as watertight doors), stability and loading information and instruments, steering gear, hull damage, the condition of ballast tanks, any kind of hull and bulkhead corrosion and cracking.

**Figure 20: Wrecked/Stranded/Grounded and Deficiencies**



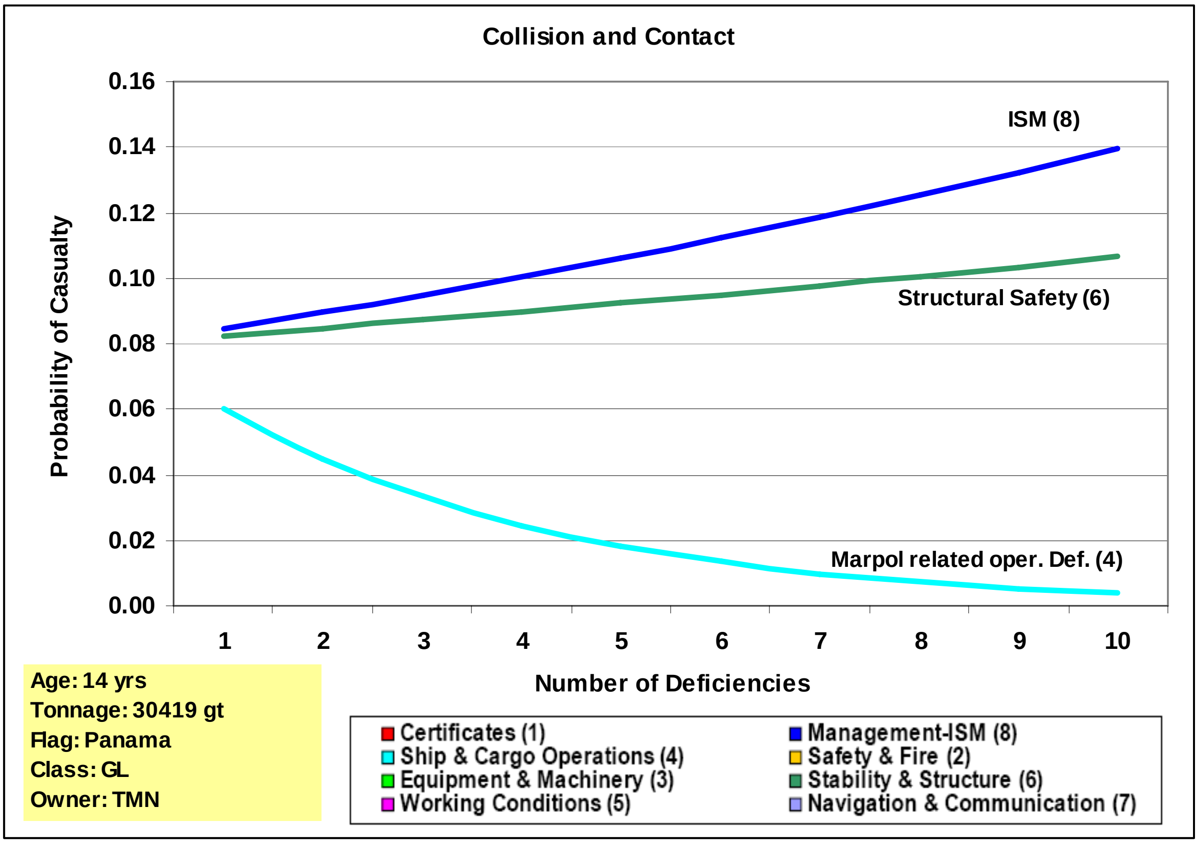
*Note: based on type III model*

Marpol related operational deficiencies (code 2100) are associated with oily mixtures in cargo spaces and other related items for cargo spaces of tankers. This code is not related to collisions and contacts and therefore cannot be interpreted. For code 900, items related to the steering gear might be very relevant in this category.

The ISM code is certainly relevant as it might show lack of enforcement of safety procedures. ISM related deficiencies contain items such the safety and environmental policy, the definition of company responsibilities and the master's responsibility, deficiencies in the area of shipboard operations, emergency preparedness, reporting and analysis of non-conformities, accidents and near misses, the maintenance of the vessel and company audits. Another area deals with resources and personnel. Violations against working and resting hours are not a separate code in the ISM group but are included in the deficiency group 200 – crew certificates.

It is difficult to interpret this graph with certainty but the strong positive effect of ISM related deficiencies shows that vessels in this category have a higher probability of having a collision or contact. It might reflect fatigue or lack of bridge procedures as well as lack of overall onboard maintenance (as reflected in code 900). From a port state control perspective, this might also mean that the deficiencies are identified but that the enforcement onboard is lacking as is the rectification of such deficiencies. Especially ISM audits (if required) cannot be done immediately unless the ship is detained. When under pressure to keep schedules, ships might proceed and ignore some of the recommendations from port state control.

**Figure 21: Collision and Contact and Deficiencies**



*Note: based on type III model*

On a short notice on ISM, the code's origins go back as far as the late 1980's when more concern arose as to the poor safety management of the industry. It was adopted in 1993[38] and had to be implemented by 1 July 2002. The last Maritime Safety Committee (MSC 81) in December 2005 presented an impact assessment of the ISM code on the industry in which several areas of improvement could be identified as follows[39]:

- *More systematic training*
- *Having an ISM Code performance measurement scheme*
- *More monitoring of compliance*
- *Integrating into employment requirements; and*
- *Involving more people, especially seafarers in writing ISM manuals.*

Given the findings in this section of this analysis, the author can fully support these recommendations. Especially the last recommendation is very relevant. From the 25 inspections and one ISM audit the author could observe during the course of this project, it has become apparent that very few management companies allow proper input from seafarers on the design and continuous improvement of the safety management system which is of direct impact of daily shipboard operations.

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[38] MSC 81/17/1, Role of the Human Element, Assessment of the impact and effectiveness of implementation of the ISM Code, 21 December 2005, page 2

[39] MSC 81/17/1/ Role fo the Human Element, Assessment of the impact and effectivness of implementation of the ISM Code, 21 December 2005, page 14

On oil and chemical tankers, it has been observed that on many occasions, the system has been designed to only serve one purpose – which is to meet the requirements of the vetting inspection questionnaires and not the overall perspective which is to improve the safety level onboard a ship by taking into consideration the particular working environment onboard a vessel. This reduces the ISM code to a paper exercise rather than a workable system for the industry. The latest addition of the oil industry's Tanker Management Self Assessment (TMSA) system in addition to ISM further proofs that ISM has reduced to a paper exercise. In theory, one safety management system should be sufficient and adaptable to the various industries within the shipping industry. TMSA allows compliance to four levels where the first level is seen to be the minimum requirement and meets the requirements of ISM.

## 4. Conclusions on Casualties – Refined View

The parameters of the variables indicating if a ship has been inspected by one of the industry vetting inspection regimes are all negative. The coefficients of the variable indicating time in-between inspections are not significant for very serious casualties but are positive for all other categories. For the casualty first events, it is only significant for fire & explosion and engine related first events.

The variables indicating where the ship was inspected is mostly negative for serious and less serious casualties and only one regime remains significant for very serious casualties (Viña del Mar Agreement on PSC) while several other regimes appear to be significant for serious and less serious casualties.

For the casualty first events, the parameters are mostly negative or not significant with the exception for engine related first events. Testing of restrictions shows that there is no significant difference with respect to the coefficients of the variables indicating where the ship was inspected and casualty first events at the 1% significance level. The strongest negative effect can be found on the probability of deck related first events (about 3%) and a slightly positive effect can be found for engine related casualty first events.

The time span in-between inspection is not significant for very serious casualties but is for less serious and serious casualties. On average and regardless of the seriousness of casualty, the probability increases by 2.3% within the time frame of one year. For fire and explosion, this increase can be 2.7% and 0.5% for engine related casualties.

With respect to the probability of casualty and frequency of inspection and detention, the probability of a casualty decreases on average while on the contrary, the probability of serious and less serious casualties increases with the frequency of inspection. The picture is similar for multiple detentions. The coefficients of the variables indicating if the ship has been detained are mostly not significant with the exception of less serious casualties and for the categories wrecked, stranded or grounded and engine related first events. For engine related first events, this variable is negative for one regime (USCG).

It is difficult to interpret the significance and the signs of the parameters of the deficiency codes towards either the seriousness and with respect to the ship types or the casualty first events since the variable is not based on the last inspection only but is a summary of all inspections that were performed prior to a casualty. Sometimes, this means an accumulation of inspections and sometimes this means, only the last inspection which was performed at least six months or less before the casualty. The analysis is therefore only being seen as a first attempt to look at both aspects closer.

What can be concluded from this portion of the analysis is that some inspections and the fact that deficiencies are found are effective towards decreasing the probability of having a casualty. This effect varies across ship types, seriousness of casualty and casualty first events. *Code 1400 (propulsion & aux. engine)* seems to be an important deficiency code while in the probability of detention does not come out to be very important in all regimes. It has a positive effect for serious and less serious casualties, in particular for dry bulk carriers and for casualty first events such as fire & explosion, wrecked/stranded/grounded and engine related casualty first events. This could indicate that there is room for improvement. It seems that deficiencies are found but due to lack of enforcement (detention) or follow up on deficiencies (detentions), the effect is positive rather than negative.

The same applies for another important code – the *ISM code* (code 2500) which captures the whole safety management system onboard a vessel. The parameter of this variable is positive for serious casualties, general cargo vessels and tankers and for casualty first event collision and contact. The ISM code captures the whole safety management onboard and its effect is only positive. It could mean that even though port state control detects deficiencies in the implementation of the ISM code onboard, the rectification or follow up on the deficiencies it not very successful and the lack of proper implementation onboard leads to an increase in the probability of having a casualty which can be very serious and serious and is more likely to be associated with a collision.

On the other hand, code *2000 (Solas operational related deficiencies)* is negative for serious casualties and engine related first events for the ship type general cargo. This could be interpreted as the effectiveness in rectifying the deficiencies and therefore having a negative effect for general cargo ships. It can also be interpreted that for instance increased drills can help in decreasing the probability of having a very serious casualty.

Another clear example is *code 1800 (gas and chemical carriers)* which is positive and significant for very serious casualties and casualty first events fire and explosion. This could be further identified as an area that should be looked at and has already been on the agenda of MSC (81) in May 2006. This finding confirms that there is problem with enforcing the legal conventions on chemical carriers but that the main contributor was identified to be of human error by not following the proper procedures.

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PSC Inspection: Flag: Syria, Ship Type: General Cargo, Surveyor: Walter De Graeve, Antwerp, July 2004

PSC Inspection: Flag: Cyprus, Ship Type: General Cargo, Surveyor: Walter De Graeve, Antwerp, July 2004

PSC Expanded Inspection: Flag: Grand Caymans, Ship Type: Bulk Carrier, Surveyor: Aarnout Salwegter, Amsterdam, August 2005

PSC inspection/Detention: Flag: Ukraine, Ship Type: General Cargo, Inspector: J. P. Van Byten, Antwerp, October 2005.

PSC safety inspection: Flag: Hong Kong, Ship Type: Dry Bulk, Inspector in charge: Ralph Savercool, New York, March 2006

PSC security inspection: Flag: Liberia, Ship Type: Container, Inspector in charge: Diane R. Semmling, New York, March 2006

PSC security inspection: Flag: Panama, Ship Type: Container, Inspector in charge: Diane R. Semmling, New York, March 2006

Flag State Inspection: Flag: Malta, Ship Type: Container, Surveyor: Henk Engelsman, Rotterdam, August 2005

Flag State Inspection: Flag: Malta, Ship Types: Bulk Carrier, Surveyor: Henk Engelsman, Rotterdam, October 2005,

Class Annual Survey and Underwater Diving Inspection: Flag: Norwegian International Register, Ship Type: Oil/Bulk Carrier, Surveyor: Yuri Sakurada, DNV, Rotterdam, March 2005

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Class Annual Survey: Flag: Malta, Ship Type: Crude Oil Tanker, Surveyor: Rob Pijper, Lloyd's Register, Rotterdam, November 2005.

Class Annual Survey: Flag: Barbados, Ship Type: General Cargo Ship, Surveyor: Pieter Andringa, Germanischer Lloyd, Rotterdam, October 2005.

Class Renewal Survey: Ship Name: Flag: Dutch, Ship Type: Chemical/Oil Product Tanker, Surveyor: Rob Pijper, Lloyd's Register, Rotterdam Damen Shipyard, August 2005

Class Follow Up: Flag: Cyprus, Ship Type: Bulk Carrier, Surveyor: Rob Pijper, Lloyd's Register, Rotterdam, September 2005

ISM Audit: Flag: Liberia, Ship Type: Juice Carrier, Surveyor: Rob Pijper, Lloyd's Register, Rotterdam, October 2005

Vetting Inspection (CDI): Flag: Dutch, Ship Type: Chemical Tanker, Inspector (CDI): Henk Engelsman, Rotterdam, August 2005

Vetting Inspection (CDI): Flag: Bahamas, Ship Type: Chemical/Oil Tanker, Inspector (CDI): Henk Engelsman, Rotterdam, October 2005;

Vetting Inspection (SIRE, Kuwait Oil): Flag: Sweden, Ship Type: Oil Tanker, Inspector (OCIMF): Henk Engelsman, Rotterdam, September 2005

Vetting Inspection (SIRE, Eni Oil): Flag: Saudi Arabia, Ship Type: Chemical Tanker, Inspector (OCIMF): Henk Engelsman, Rotterdam, October 2005;

Vetting Inspection (SIRE, Statoil): Flag: Sweden, Ship Type: Tanker, Inspector (OCIMF): Henk Engelsman, Rotterdam, June 2006

Vetting Inspection (SIRE, Statoil): Flag: Liberia, Ship Type: Oil Tanker, Inspector (OCIMF): Henk Engelsman, Rotterdam, June 2006

Vetting Inspection (Rightship): Flag: Hong Kong, Ship Type: Dry Bulk Carrier, Inspector (Rightship): Dennis Barber, Ijmuiden, March 2006

P&I Club Inspection: Flag: Greece, Ship Type: Bulk Carrier, Inspector: Walter Vervloesem, Ghent, October 2005;

Marpol Inspection: Flag: Norway, Ship Type: Oil Tanker, Port Superindendent: Mr. Cees-Willem Koorneef, Rotterdam, August 2004

Marpol Inspection: Flag: Panama, Ship Type:OBO, Port Superindendent: Mr. Cees-Willem Koorneef, Rotterdam, August 2004

Ship Visit (VLCC): Flag: Bahamas, Ship Type: Oil Tanker, Class: ABS, Rotterdam, October 2005

# Appendix

### Appendix 1: Grouping of Countries of Ownership

The grouping of ownership of a vessel was made according to Alderton and Winchester (1999) and is as follows:

1. *Old Open Registries:* Antigua and Barbuda, Bahamas, Bermuda, Cyprus, Honduras, Liberia, Malta, Marshall Islands, Panama, St. Vincent & the Grenadines

2. *New Open Registries:* Barbados, Belize, Bolivia, Cambodia, Canary Islands, Cayman Islands, Cook Islands, Equatorial Guinea, Gibraltar, Lebanon, Luxembourg, Mauritius, Myanmar, Sri Lanka, Tuvalu and Vanuatu

3. *International Registries:* Anguila, British Virgin Islands, Channel Islands, DIS, Falklands, Faeroes, Hong Kong, Isle of Man, Kerguelen Islands, Macao, Madeira, NIS, Philippines, Sao Tome and Principe, Singapore, Turks and Caicos, Ukraine, Wallis and Fortuna, Netherlands Antilles

4. *Traditional Maritime Nations:* Argentina, Australia, Austria, Belgium, Brazil, Canada, Chile, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Japan, Mexico, Netherlands, New Zealand, Norway, Portugal, Russia, South Africa, Spain, Sweden, Switzerland, UK, Uruguay, USA, Venezuela.

5. *Emerging Maritime Nations:* Albania, Algeria, Angola, Azerbaijan, Bahrain, Bangladesh, Benin, Brunei, Bulgaria, Cameroon, Cape Verde, China, Colombia, Comoro, Congo, Costa Rica, Croatia, Cuba, Djibouti, Dominica, Dominican Republic, Egypt, El Salvador, Ecuador, Eritrea, Estonia, Ethiopia, Fiji, Gabon, Gambia, Georgia, Ghana, Grenada, Guatemala, Guinea, Guyana, Haiti, Hungary, India, Indonesia, Iran, Iraq, Israel, Jamaica, Jordan, Kazakhstan, Kenya, Kiribati, North Korea, South Korea, Kuwait, Laos, Latvia, Libya, Lithuania, Madagascar, Malaysia, Maldives, Mauritania, Micronesia, Morocco, Mozambique, Namibia, Nicaragua, Nigeria, Oman, Pakistan, Papua New Guinea, Paraguay, Peru, Poland, Qatar, Romania, St. Helena, St. Kitts & Nevis, Samoa, Saudi Arabia, Senegal, Seychelles, Sierra Leone, Slovakia, Slovenia, Solomon Islands, Somalia Republic, Sudan, Surinam, Syria, Taiwan, Tanzania, Thailand, Togo, Trinidad, Tunisia, Turkey, Turkmenistan, UAE, Vietnam, Yemen

6. *Other/Unknown:* Undefined by dataset, Unknown (Fairplay), Azores, Cameroon, Greenland, Monaco, Puerto Rico, Serbia & Montenegro, St. Pierre & Miquel