SABINE KNAPP

The Econometrics of Maritime Safety

Recommendations to Enhance Safety at Sea

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Recommendations to enhance safety at sea

De econometrie van maritieme veiligheid
Aanbevelingen om de veiligheid op zee te vergroten

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Sabine Knapp
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Doctoral Committee

Promotor:
Prof.dr. Ph.H.B.F. Franses

Other members:
Prof.dr.ir. R. Dekker
Prof.dr. P.J.F. Groenen
Prof.dr. S. Kumar

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The full appendix is not included in the printed version of this thesis due to the large volume of pages. The appendix as well as an electronic version of the thesis can be found under the following location: http://hdl.handle.net/1765/7913 for further reference.

„Gewidmet allen Seemännern - insbesondere aber meinem Großvater Anton“
(“To all seafarers – especially my grand father Anton”)

Salum Et Carinae Pignora Vitae
(To the open seas and keel of a ship we pledge our lives)[1]

[1] Courtesy of RINA (Royal Institution of Naval Architects)

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List of Abbreviations

AIS	Automatic Identification System
AMSA	Australian Maritime Safety Authority
BC	Code of safe practice for solid bulk cargoes
BCH	Code for the construction and equipment of ships carrying dangerous chemicals in bulk
BLU	Code of practice for the safe loading and unloading of bulk carriers
CAP	Condition Assessment Program
CAS	Conditions Assessment Scheme
CBT	Clean Ballast Tanks
CCSS	Code of Safety for Caribbean Cargo Ships
CDI	Chemical Distribution Institute
CL	Classification Society
CMOU	Caribbean Memorandum of Understanding
COLREG	Convention on the International Regulations for Preventing Collisions at Sea
COW	Crude Oil Washing
CSR	Continuous Synopsis Record
CSS	Code of safe practice for cargo stowage and securing
DoC	Document of Compliance
DWT	Deadweight
EC	European Community
EEBD	Emergency Escape Breathing Device
EMSA	European Maritime Safety Agency
EPIRB	Emergency position indicating radio beacons
ESP	Enhanced Survey Program
EU	European Union
FL	Flag State
FSA	Formal Safety Assessment
FSS	Fire Safety Systems Code
GCH	Old Gas Carrier Code for ships constructed before 1st October 1994 as per resolution MSC 5 (48)
GISIS	Global Integrated Shipping Information System
GDP	Gross Domestic Product
GMDSS	Global Maritime Distress and Safety System
GPS	Global Positioning System
GT	Gross Tonnage
HS	High Speed
HSC	International Code of safety for high-speed craft
IACS	International Association of Classification Societies
IBC	International Code for the Construction and Equipment of ships carrying dangerous chemicals in bulk (constructed after 1st July 1986)
IGC	International Code for the construction and Equipment of Ships Carrying Liquefied Gas in Bulk
ILO	International Labor Organization
IMDG	International Maritime Dangerous Goods Code: contains classification, packing, marking, labeling and stowage of dangerous goods in packaged form
IMO	International Maritime Organization

IMOU	Indian Ocean Memorandum of Understanding
INTERCARGO	International Association of Dry Cargo Shipowners
INTERTANKO	International Association of Tanker Owner
ISM	International Safety Management Code
ISPS	International Ship and Port Facility Security Code
ITOPF	International Tankers Owners Pollution Federation
LI	Legal Instrument
LM	Lagrage Multiplier
LMIU	Lloyd's Maritime Intelligence Unit
LN	Natural logarithm
LSA	International Life Saving Appliance Code
MARPOL	International Convention for the Prevention of Pollution from Ships
ML	Maximum likelihood
MoU	Memorandum of Understanding
OBO	Combination Carrier
OCIMF	Oil Companies International Marine Forum
OECD	Organization for Economic Co-operation and Development
OLS	Ordinary Least Squares
OPA	Oil Pollution Act
OWN	Ship's Owner
PMOU	Paris Memorandum of Understanding
P&A	Procedure and Arrangement Manual
P&I	Protection and Indemnity
PS	Port State
PSC	Port State Control
QML	Quasi-maximum likelihood
RO	Recognized Organization
Ro-Ro	Roll On – Roll Off
RS	Russian Maritime Register of Shipping (Russia)
SART	Search and rescue transponders
SBT	Segregated Ballast Tanks
SIRE	Ship Inspection Report Program
SIReNAC	Central information system for port state inspection records
SMPEP	Shipboard Marine Pollution Emergency Plan
SOLAS	International Convention for the Safety of Life at Sea
SOPEP	Ship Oil Pollution Emergency Plan
ST	Ship Type
STCW	International Convention on Standards of Training, Certification and Watch keeping for Seafarers
TBT	Tributyltin
TONNAGE	International Convention on Tonnage Measurement of Ships
UN	United Nations
UNCLOS	United Nations Convention on the Law of the Sea
UNCTAD	United Nations Conference on Trade and Development
UMS	Unmanned machinery spaces
US	United States of America
USCG	United States Coast Guard
VMOU	Viña del Mar Agreement on Port State Control
VDR	Voyage Data Recorder
VLCC	Very large crude carrier

Acknowledgements

Much improvement in the safety of life at sea has been accomplished since the era of the last sailing vessels beating their way around Cape Horn where lives were lost each voyage. Today, the legal framework to enhance safety at sea and to protect against pollution is complex and the seagoing profession has changed over the last ten years where more control and complex daily operations have eroded some of the seamanship found on ships that had to face the challenges of the seven seas without shore-side assistance.

Despite the fact that there is a lack of trust amongst most players in the industry, there is considerable concern about safe and environmentally friendly operations from most ship owners and operators. Nevertheless, the safety system, as complex as it may be, due to its international structure provides loopholes for substandard ships to trade and to distort competition and there is still room to improve the daily lives and working conditions of some seaman.

Having sailed myself for ten years across the seven seas, the shape of my life has been strongly influenced by my dedication towards the sea despite the fact that I come from a non maritime nation. I hope that the work presented in this thesis provides a useful contribution towards finding a solution to a topic that I feel is complicated and very political in nature as too much emphasis is placed on national interest. None of this work would have been possible without the help and cooperation of many people who I would like to acknowledge shortly here and I hope that I have not forgotten anybody.

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From the vetting inspection regimes, the most helpful persons for this project were *Henk Engelsman* (CDI/OCIMF) and *Capt. Warwick Norman* (Rightship). I was allowed to observe vetting inspections on chemical tankers, oil tankers and dry bulk carriers. In particular Henk was always very helpful and provided me with information and his extensive knowledge about shipping derived from his experience as being a former

[2] Lloyd's Maritime Intelligence Unit

captain and inspector for many years. Finally, I would like to acknowledge the Greenaward Foundation, in particular *Capt. Jan Fransen* for supplying me with data which I incorporated into my overall dataset. I would like to extend special thanks to *Aarnout Salwegter* from the Dutch Shipping Inspectorate for taking me along on several port state control inspections in Rotterdam and for sharing his opinion about inspections in general. The same applies to the Belgium PSC office and in particular to *Walter de Graeve* and *J.P. van Byten* for taking me along on several inspections in Antwerpen of which I could also witness the process of a detention. I would also like to acknowledge *Walter Vervlosem* who has taken me on a P&I Club inspection in Ghent and who has brought the maritime insurance world a bit closer to me.

In particular I would like to thank all the seaman and officers onboard the vessels I visited including their designated persons ashore and superintendents. The cooperation of the ship owners or operators was in general very good. It is always interesting to visit a vessel since one is treated well by the people onboard. For me, each of these visits reminded me at my own time at sea but also showed me the reality of shipboard life and operations in the commercial shipping industry which is quite different from the cruise industry – the industry I came from. It also gave me insight into the complex daily operations that are on some of the vessel. In particularly, I enjoyed the discussions and interesting stories from various captains and chief engineers connected with these visits and their genuine hospitality. I would like to thank *Capt. George Ntallaris* for his explanation on iron ore cargo operations, *Capt. John Dudley* for his insight into tanker operations, *Dick Pas* for his time and discussions about IMO and *Dennis de Witte* for his support in organizing additional ship visits.

Finally, I would like to thank the last group of people from the Econometric Institute at Erasmus University for their time and patience to help me improve my econometric skills. I would like to mention *Michel van de Velden* and thank him for letting me use a program of his for the correspondence analysis, *Govert Bijwaard, Michiel de Pooter and Richard Paap* – for their time and discussion about the logit model, maximum likelihood estimation and heteroscedasticity. I would also like to thank *Michiel, Francesco and Chen* for their friendship which helped me fight the loneliness in writing this thesis. Further, I would like to thank *Christiaan Heij* and *Jan Brinkhuis* for allowing me to follow one of their courses and for their moral support. I particular enjoyed my lunch sessions with Jan and the encouraging words of both – Christiaan and Jan during the last phase of my PhD. I will certainly miss that and hope to be able to work on future publications in this area with some of the members of the Econometric Institute. Also special thanks to Jan and *Chantal Cheung-Tam-He* for helping me in producing a Dutch translation of the abstract.

Many thanks are also given to my friend and long-time ship mate, *Wayne Bornio* who has taken the time to perform some of the proof-reading of this thesis. But last not least, I would like to thank my friend *Gert-Jan Huisink* whose discussions and friendship has helped me throughout my time in Rotterdam. Gert-Jan always had a supportive word for me and encouraged me in the last and most difficult phase of this thesis. The same applies to *Jose Lucas* who always had some good words of support for me. I would like to thank my *parents and family* for their understanding and their help in adapting to shore based life during the last three years.

Overall, I rate the experience in conducting my research and in writing up this thesis as a positive accomplishment. The only regret I do have is that I did not have enough time to look into all possible aspects of my vast dataset but in the final stage of the PhD, I accepted that some areas can be left open for further research.

Abstract

This thesis should be seen and understood as a first attempt to study port state control on a global scale by measuring the effect of inspections on the probability of casualties and by identifying areas for improvement. What is new in this thesis is the combination of port state control data from various regimes and casualty data from three different sources of the same time frame. The corresponding research questions are 1) What is the present state of the safety regime? 2) Can targeting of ships for inspections be improved? 3) What is the effect of inspections on casualties? and 4) How can inspections be improved? It is based on approx. 183,000 port state control (PSC) inspections and 11,000 casualties from 1999 to 2004. The thesis will hopefully open up a new chapter in research in the area of maritime safety of which the future potential, when political barriers are overcome and more transparency is accepted, should not be ignored by the industry and regulators. Several econometric techniques are used to produce probabilities of detention and casualties either per seriousness or casualty first events. The author does not take any political dimensions of flag state implementation or port state control into consideration but solely concentrates on the technical aspects of the topic in question.

The maritime industry is characterized by a heavy legal framework based on international law with limited legal enforcement possibilities in case of non compliance. This creates loopholes and distortion to competition due to the existence of a market of substandard ships. From a public perspective, the desired situation is to promote safe, secure and environmentally friendly maritime transportation and to decrease the number of substandard vessels. Flag states are to be seen as the first line of defense in eliminating sub-standard vessels followed by the second line of defense, the port states. The lack of trust in the industry has created a playground for inspections on certain ship types. A considerable amount of industry driven inspections are performed where total inspections are estimated to be at 11 inspections per year for tankers, 6 for dry bulk carriers and 5 for all other ship types.

Two areas of potential improvement have been identified: 1) the targeting of ships for inspections and 2) the inspections and follow up on deficiencies themselves. At first sight, it seems that too many ships with zero deficiencies are targeted but when aggregated by ship and across regimes, the percentage of ships with zero deficiencies diminishes significantly over the given time period. Nevertheless, a certain group of vessels (about 7% of ships eligible for port state control) has been identified to be over-inspected and efforts should be made to shift inspection efforts towards the groups of ships that can benefit from an inspection which is estimated to be at about 14% of all port state control eligible ships based on the time period used for this analysis. The effect of port state control inspections towards the probability of casualty can be measured for very serious casualties but not for serious and less serious casualties. Depending on the overall risk profile of a vessel, an inspection can potentially decrease the probability of having a very serious casualty by approx. 5% per inspection where the effect can be as strong as 10% for very high risk vessels.

While key figures on deficiencies and detentions vary accordingly across the regimes, the difference towards the probability of detention is merely reflected by the differences in port states and the treatment of deficiencies and not necessarily by age, size, flag, class or owner. The target factor can be improved by developing a target factor on combined inspection data taking the total ship's inspection history into account. Furthermore regional differences can be allowed since high risk areas were identified for West Africa,

the Indian Ocean region, the North Atlantic East region and the South China Sea. The difference in the effect of inspections on the probability of casualty for either seriousness or casualty first events further confirms a shift of sub-standard vessels from areas such as the Paris MoU and the USCG to other areas of the globe such as the South American Region, the Indian Ocean Region or Australia. Inspections of these regimes have shown to decrease the probability of having a casualty.

The classic variables such as ship type, age, size, flag, the classification society, deficiencies found in prior inspections and detention are all valid variables for targeting sub-standard ships. Flag is only one variable out of many variables that can be used to target sub-standard ships. Age only remains significant for very serious casualties and as the age of the vessel increases, the probability of having a very serious casualty increases by about 12% over a 35 year period which translates into about 0.35% per year. The probability of casualty further confirms that general cargo vessels are ships with the highest probability of a casualty which is confirmed by the probability of detention. Black listed flag states or non inspected ships show a higher probability of a very serious casualty compared to grey and white listed flag states while the same does not hold for serious and less serious casualties. Average insurance claim costs on the other hand reveal that highest claim costs are associated with tankers and passenger vessels.

Further improvements on targeting sub-standard ships can be made by adding the variable indicating the ownership or DoC[3] Company of a vessel and certain data on ship history such as change of class, class withdrawal and change of ownership over time or where the ship was primarily built, all of which have either shown a positive or negative effect on the probability of casualty. Another possibility would be to include if a vessel had been inspected by one of the vetting inspection[4] regimes (for dry bulk) or certified by the Greenaward Foundation.

A refined view on the effectiveness of inspections reveals that detention does not seem to be significant towards the probability of having a casualty and which is a surprising result. It does not necessarily mean that detention is not relevant but that the effect might be captured by the inspection. Furthermore, the time span in-between inspections 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. Basic ship risk profile across all regimes lies between 0.5% to 1.5% for most ship types and regimes while the average probability of casualty aggregated for all ship types has been identified to be 0.06% for very serious, 1.6% for serious and 1% for less serious casualties.

The probability of detention models revealed the highest contribution of deficiencies towards detention in the areas of certificates, ship and cargo operations, the ISM[5] code and safety & fire appliances while lowest contribution is found for machinery and equipment. The probability of casualty either per seriousness of casualty or casualty first event also revealed three areas of interest – the ISM code, ship and cargo operations and machinery and equipment. Those are the main areas which have been identified where room for improvement exists for port state control inspections in order to decrease the probability of a casualty.

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[3] Document of Compliance Company, the designated company responsible for the safety management onboard a vessel according to the International Safety Management Code (ISM)

[4] vetting inspections are performed by the industry (the oil majors or the chemical industry)

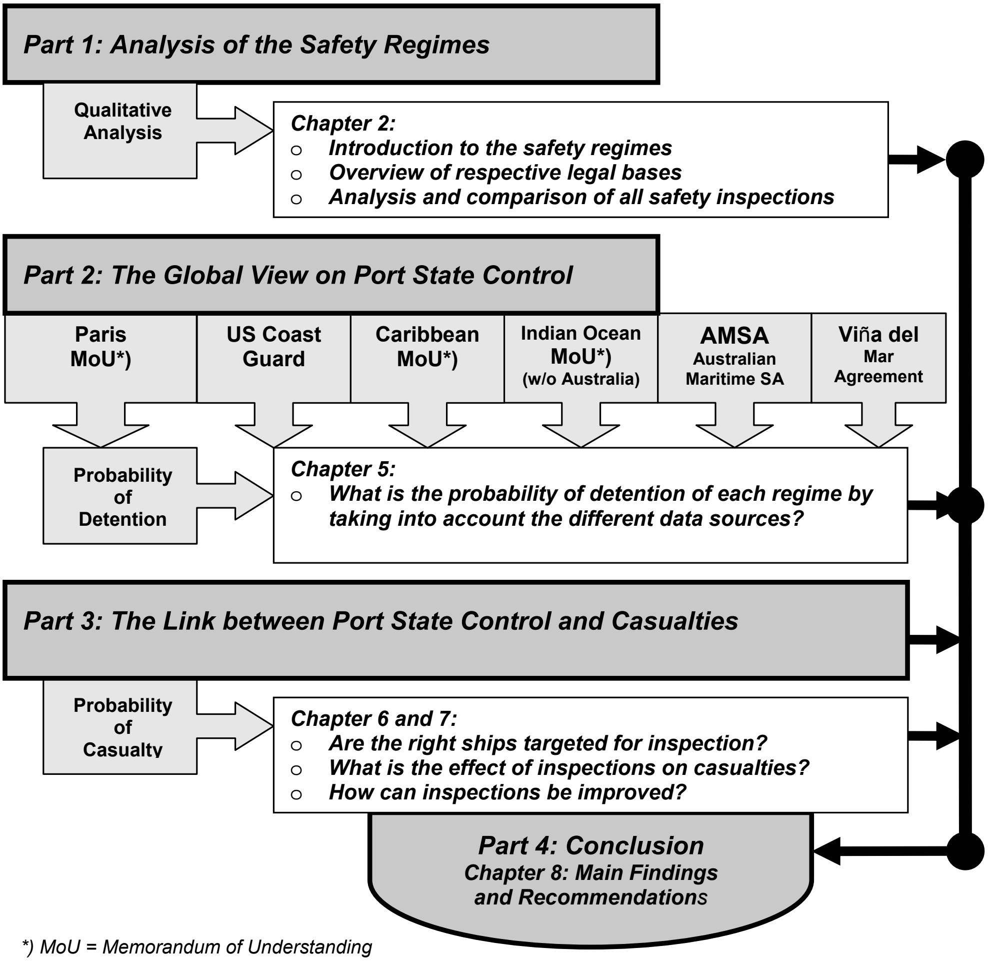
[5] International Safety Management Code

Chapter 1: Research Question and Methodology

1.1. Research Questions

The maritime industry is characterized by a heavy legal framework based on international law with limited legal enforcement possibilities due to the absence of a court of justice who can initiate legal proceedings in case of non compliance. This creates loopholes and distortion to competition due to the existence of a market of substandard ships. From a public perspective, the desired situation is to promote safe, secure and environmentally friendly maritime transportation and to decrease the amount of substandard vessels. The objective of this thesis is to make some recommendations to contribute towards this objective. Figure 1 lists the main research areas and questions which are divided into four parts.

Figure 1: Description of Research Areas and Questions



*) MoU = Memorandum of Understanding

Chapter 2 gives an overall introduction to the safety regimes, the inspection regimes and their associated costs and frequencies. It further provides an overview of the legal bases when applicable. *Chapter 3* explains the datasets and the processes for variable transformations which are used in chapter 4, 5, 6 and 7 of this thesis. It further provides definitions of variables used in this thesis.

Chapter 4 gives an in-depth analysis of some of the Port State Control Regimes today and is based on 183,819 port state control inspections from various regimes around the world. It produces the probabilities of a ship being detained across the regimes split into ship types and will take into account the fact that the datasets come from different data sources.

Chapter 5 provides an overview of casualty key statistics as well as an explanation on the types of regressions used for the casualty analysis. *Chapter 6* makes the link between port state control and casualties by looking at the inspection and casualty history of the ships from the datasets. It measures the effect of inspections on casualties and tries to evaluate the target factor. *Chapter 7* provides a more detailed view and tries to identify how inspections can be improved. The main research questions can be summarized as follows:

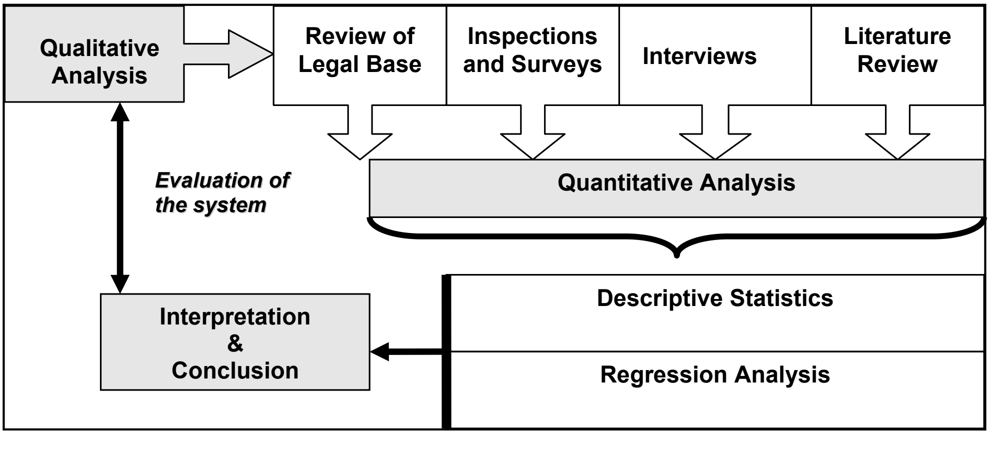
1. What is the present state of the safety regime?
2. Can targeting of ships for inspection be improved?
3. What is the effect of inspections on casualties?
4. How can inspections be improved?

Chapter 8 provides an overall conclusion to the findings drawing from all the other areas and gives a recommendation on how to improve the system.

1.2. Methodology

To analyze the safety and inspection regimes from all possible angles and to obtain the best overview as well as to establish the connection to the daily shipboard life, the following research methods for this thesis were used and are shown in Figure 2 below.

Figure 2: Overview of Research Methods



First, the author conducted a qualitative analysis by reviewing the respective legal bases in order to gain a better understanding of the complexity of the system. The legal base is split into *international law* such as the international conventions and the memoranda of understanding and applicable *national law* for each of the port state control regimes. National laws in particular apply to the US, Australia and the EU where EU law (either directives or regulations) is supreme to national law.

For the review and understanding of the various inspection regimes, the author joined *inspections and surveys* as observer and conducted interviews with the inspectors, ship owner's associations, port state control officials, ministry officials', classification societies and insurance companies. The different types of inspections and surveys were chosen in order to cover the *mandatory (statutory)* inspections performed by flag states, classification societies and port states and the *non mandatory* inspections performed by the industry (vetting inspections). A variety of inspections (27 inspections and 1 visit) were therefore observed on various ship types (general cargo, dry bulk, oil tanker, chemical tanker, container vessels) as follows[6]:

1. Flag state inspections (2)
2. Port state control: initial/more detailed (5 including one detention) and expanded inspection (1), security inspection (2)
3. Classification Societies: annual (4) & renewal (1) inspection, ISM audit (1), detention follow up (1)
4. Vetting inspections: CDI[7] for chemical tankers (2), OCIMF[8] (4) for oil tankers
5. Vetting inspection for Rightship for dry bulk carriers (1)
6. Insurance Companies: Protection & Indemnity (P&I) Club (1)
7. Other Inspections and Visits: MARPOL (2), 1 Visit to a VLCC (1)

The port state control inspections were performed in the Netherlands, Belgium and in the US (New York) where security inspections are performed separately from safety inspections. Security has not been taken into consideration for this thesis since the ISPS[9] Code only came into force in July 2004. The knowledge and oversight gained by the inspections and interviews was then used in the decision process of the variables used in the various analyses as well as to help interpreting the data. In addition, an insight into the various shipboard operations which vary according to the ship types was gained.

A literature review was performed primarily on relevant topics in econometrics and on the literature connected to the legal framework as well as literature connected to safety and casualty analysis. Soma (2004)[10] lists the many different levels of maritime safety which have been addressed by researchers so far and splits the areas into five levels (accidents, ship standards, organization, management and environment) where each level contributes towards the overall safety level of a vessel. In addition, Talley (1999 ff)[11] in his work has looked at determinants of crew injuries (1999), oil spillage costs (2001) and vessel damage costs (2002) using similar econometric techniques presented here.

This thesis does not look into root causes for casualties due to the inadequate quality of casualty data nor does it cover all the levels described by Soma (2004) but emphasis is given on the evaluation of the effectiveness of the safety regimes, in particular port state

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[6] Number in brakes is the amount of inspections
[7] CDI – Chemical Distribution Institute
[8] OCIMF – Oil Companies International Marine Forum
[9] International Ship and Port Facility Security Code
[10] Soma, T. (2004), Blue-Chip of Sub-Standard, Tronheim, page 190
[11] Talley, W.K – for further reference on his articles, please refer to the references.

control by measuring the effect of inspections on the probability of a casualty. It is looking at the subject from a more regulatory or public perspective which is to enhance safe and environmentally friendly maritime transportation. The combination of the data used in this study is new due to the various barriers in obtaining raw data on a ship level. The data for this section comprises incidents, accidents and casualties and the definitions thereof are presented in Chapter 3. The quantitative part of the thesis consists mainly of regression analysis based on various combinations of datasets.

The author would like to point out that with respect to the rule making process at IMO, the organization has developed in 2001 and 2002 guidelines for *Formal Safety Assessment (FSA)*[12] which should enhance rule making based on risk assessment and cost benefit analysis. It is worthwhile noticing that some results of this thesis could possibly be incorporated into future FSA studies.

1.3. Overview of Datasets and Variables Used

Three datasets have been used for the analysis and their relation can be seen in Figure 3. Set A consists of the inspection database of 183,819 inspections from various Memoranda of Understanding (MoU[13]) listed in Figure 1 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[14] where the average amount of inspections per vessel is by 7 per ship or 1.7 inspections per ship per year.[15]

Set C represents an approximation of the total ships in existence[16]. Out of these vessels, ships below 400 gt[17] and ship types which are not eligible for port state control inspection 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 of vetting inspection information[18] on oil tankers and dry bulk carriers from Rightship. In addition, oil tankers which are certified by Greenaward have also been

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[12] MSC/Circ.1023, MEPC/Circ.392 of 5th April 2002 and MSC 81/18 of 7th February 2006

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

[14] 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.

[15] 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.

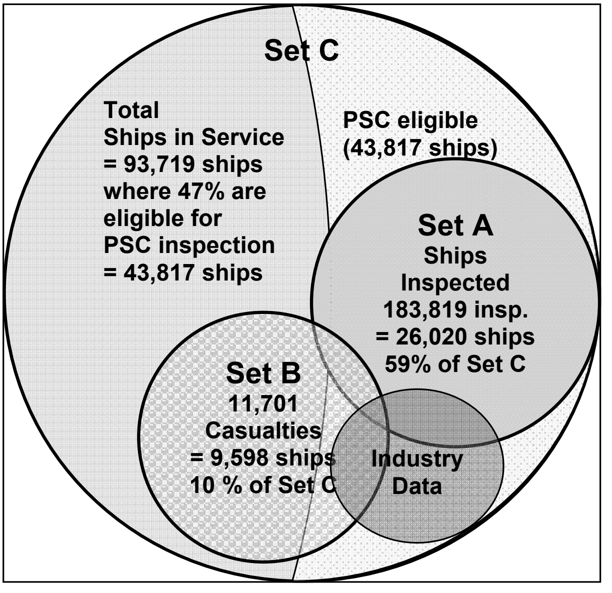
[16] As per data received from Lloyd's Register Fairplay.

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

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

identified. The casualty and industry data is linked to the port state control data by the IMO number and within the same time frame.

Figure 3: Overview of Datasets Used



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[19] 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 elimination of port state control relevant casualties is explained in detail in Chapter 5. A portion of the fishing fleet (above 400gt) is treated separately in the casualty analysis.

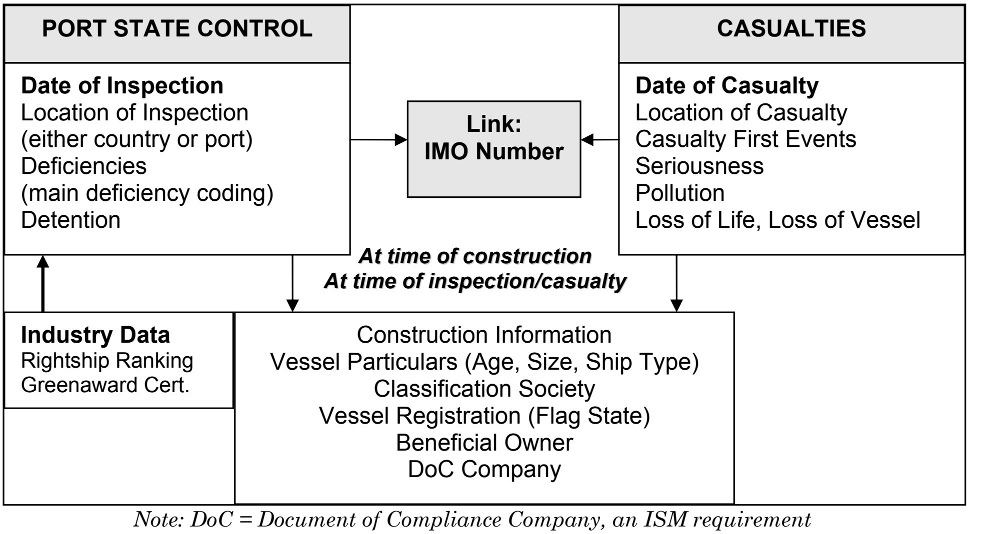
The sets are used in various ways depending on the kind of analysis which is conducted. In essence, the combination of these datasets gives insight into the amount of ships that are inspected/not inspected, detained/not detained and have/do not have a casualty with their respective combinations. Figure 4 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.

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)[20]. The incorporation of the ownership of a vessel is not a straight forward task in shipping and requires some careful thinking.

[19] Lloyds Maritime Intelligence Unit
[20] it follows a ranking performed by the Paris MoU each year where white listed flag states perform best followed by grey and black listed flag states.

Two types of variable groups have therefore been used. The first one concerns information on 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"[21]. Definitions on both types are provided in Chapter 3 where variables, their groupings and transformations are explained in detail. The Document of Compliance Company is the company that is responsible for the safety management of the vessels.

Figure 4: Overview of Variables Used



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

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. It is important to indicate that a more refined result in part III of this thesis could have been obtained if additional data from the Asian region would have been made available for this thesis. The following chapter continues with an overall introduction to the safety regime as well as its current legal bases.

[21] Based on Lloyd's Register Fairplay data of the "World Shipping Encyclopedia CD" and Lloyd's "Maritime Database CD" plus custom made queries on ownership and construction detail history.

PART I

This part contains two chapters and provides a general overview of all players in the safety regime and how they interact as well as the major trade flows in order to provide the necessary understanding of the industry for the quantitative analysis.

It further analyzes all inspections that are performed onboard ships in the name of safety and tries to establish their frequency and costs. In addition, insight into average insurance claim costs (above the deductibles) is given. Applicable legal bases and their respective new developments in the area of safety and port state control are listed and analyzed.

Part I ends with an explanation of all the variables and the dataset preparations that were performed to be used for the quantitative part including the selection of ship types.

Chapter 2: Analysis of the Present Safety Regimes

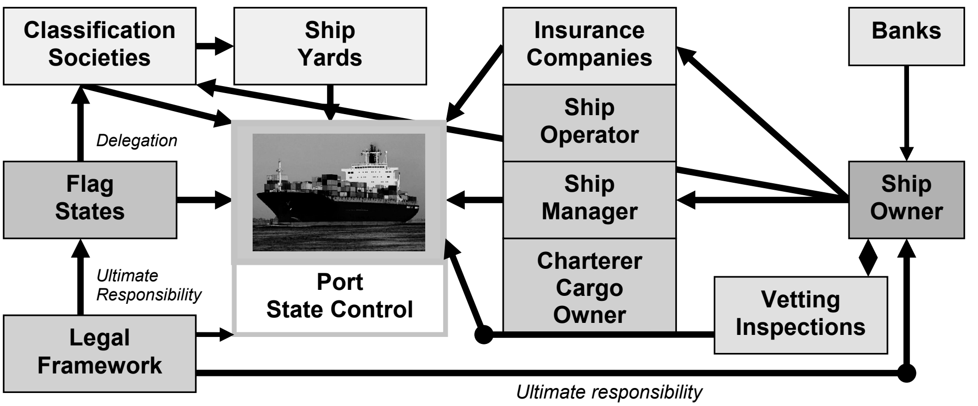
This chapter provides an introduction to the safety regimes and the inspection regimes by explaining the players of the safety regime and gives a short overview of the legal bases and target factors of each of the port state control regimes. In addition, the various inspections which are performed on ships and their associated costs are explained in detail to provide a better understanding of the complexity of the system.

2.1. The Complexity of the System

2.1.1. The Players of the Regime

Figure 5 provides an overview of the players of the safety regime which at first sight seems complex. The legal framework is created by three major international organizations namely, the UN, ILO, and the IMO[22] and country specific legislation[23]. The classification societies provide the technical expertise during ship building and technical maintenance of the vessel. In addition, classification societies can be authorized to perform statutory responsibilities on behalf of the flag states that have the ultimate responsibility to enforce their legal base which can be a combination of the international conventions of which the flag state is signatory or its own legal base while the ship owner has the ultimate responsibility to comply with the combined legal bases.

Figure 5: Players of the Safety Regime in General



The line between the actual ship owner, operator or technical manager of the vessel is not completely clear in shipping and therefore complicates enforcement of the legal instruments. In an effort to gain some insight into the relationships, data from Lloyd's Register Fairplay was merged with the total dataset as explained previously. The reason of the existence of the port state control regime derives from the fact that a certain percentage of ship owners and flag states use the legal "loophole" created by the international legal framework and try to save costs by operating below the minimum safety standards. This can cause accidents and damage to the environment, the cargo and

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[22] UN: United Nations, IMO: Intern. Maritime Organization, ILO: Intern. Labor Organization

[23] This could be for instance the *"acquis communautaire"* for the EU or OPA 90 for the US or any other country specific legislation

human lives. According to the OECD the percentage of sub-standard ships in the world commercial fleet is estimated to be between 10-15%[24]. The industry solution to this problem is represented by the vetting inspections which are performed on oil tankers, chemical tankers and bulk carriers. The vetting inspections create a strong commercial incentive for the ship owner to comply to the vetting inspection requirements since the outcome of these inspections will determine if the ship gets cargo or not. The various types of inspections that are performed on ships including port state control inspections will be explained in detail later on in this chapter. A possible first step to improve enforcement is the implementation of the IMO Voluntary Flag State Audit Scheme which has been adopted in December 2005 and will also be explained later on in this chapter.

Port State control can be seen as a last resource of safety to eliminate substandard ships from the seas. Worldwide, there are currently ten safety regimes in place to cover most of the coastal states. Those regimes are as follows:

1. Europe and North Atlantic (Paris MoU)
2. Asia and the Pacific (Tokyo MoU)
3. Latin America (Acuerdo de Viña del Mar)
4. Caribbean (Caribbean MoU)
5. West and Central Africa (Abuja MoU)
6. Black Sea (Black Sea MoU)
7. Mediterranean (Mediterranean MoU)
8. Indian Ocean (Indian Ocean MoU)
9. Arab States of the Gulf (Riyadh MoU)
10. US (US Coast Guard).

The first port state control regime that came into place was the Paris MoU in 1982[25] followed by the others listed previously and noting the standards listed in IMO Resolution A.682 (17)[26] calling for regional co-operation in ships inspections while Resolution A 787 (19) with its amendment of A 822(21) provides guidelines on the procedures to conduct port state control inspections. Table 1 gives an overview of the safety regimes used in this analysis with an indication of the years they exists and the number of members as of 2005 where a detailed list of the member states can be found in Appendix 1 for further detail.

Table 1: Key Figures on Safety Regimes

Safety Regime	**MoU Signed**	**Years in Existence (in 2005)**	**Number of Members**
Paris MoU	1982	23	22
Caribbean MoU	1996	9	22
Viña del Mar	1992	13	13
Indian Ocean MoU	1998	7	18
Tokyo MoU (AMSA)	1993	12	18
USCG	Primarily 1994	n/a	n/a

Although AMSA is part of the Tokyo MoU and the Indian Ocean MoU, the details of the Tokyo MoU are only listed as a reference and for the various analyses; AMSA is treated as individual country like the USCG.

[24] Peijs, K. (2003). Ménage a trois. Speech at *Mare Forum* (November 2003: Amsterdam)
[25] Paris Memorandum of Understanding on Port State Control, 19th May 2005
[26] IMO Resolution A.682 (17) calls for the regional co-operation in ship inspections

Table 2: List of Legal Instruments, Targeting and Inspection Systems per MoU (part 1)

	Paris MoU		Caribbean MoU		Viña del Mar	
Memorandum Signed/Take Effect	**1982**		**1996**		**1992**	
Years in Existence as per 2005	**23**		**9**		**13**	
Relevant Instruments	**Convention**	**Protocols**	**Convention**	**Protocols**	**Convention**	**Protocols**
1) Load lines 66 & Protocol 88	yes	yes	yes	not specified	yes	yes
2) SOLAS 74 & Protocols 78 & 88	yes	yes	yes	yes	yes	yes
3) MARPOL 73/78 with Protocol 78 & 97	yes	yes	yes	yes	yes	yes
4) STCW 78 & Amendments of 95	yes	n/a	yes	n/a	yes	n/a
5) COLREG 72	yes	n/a	yes	n/a	yes	n/a
6) TONNAGE 69	yes	n/a	yes	n/a	yes	n/a
7) ILO Conv. Nr. 147, 1976 & Prot.96	yes	yes	yes	not specified	not specified	not specified
8) The Intern. Conv. on Civil Liability for Oil Pollution Damage, 1992 Protocol.	n/a	yes	not specified	n/a	not specified	n/a
9) Treatment for ships flying a flag not party to the legal instruments	no favorable treatment		no favorable treatment		no favorable treatment	
10) Other Legal Instruments	EC Directive 21/95 and 106/01		Code of Safety for Caribbean Cargo Ships (CCSS Code) for ships below 500gt		not relevant	
Targeting System						
1) Amount of ships to be inspected:	25% of ships entering area per year		15% of est. number of foreign merchant ships per year		at least 15% of foreign ships per year	
2) Variables used for targeting:	Flag, Class, Size, Age, Ship Type, inspections history of the area only		Flag (above average detention), Size (below 500gt), Ship Types (carrying harmful substances), Previous Deficiency History		Flag, Class, Size, Age, Ship Type, inspections history of the area only	
3) Targeted ship types either by type/age or size:	general cargo, bulk carrier, gas carrier, chemical tanker, oil tanker, passenger		general cargo ships, passenger ships, Ro-Ro, oil tankers, gas carriers, chemical tankers		passenger ships, ro-ro vessels, bulk carriers, oil tankers, gas carriers, chemical tankers	
4) Time criteria	if entering area for the first time in the last 12 months or if not inspected in the last 6 m		ships not inspected within the last six months by another member state		avoid inspection if vessel was inspected within the preceding 6 months	
5) Quantitative Target Factor:	> 50 points inspection mandatory		no quantitative system		yes but not obligatory	
6) Deficiency Coding	standardized deficiency coding		coding as per Paris MoU		coding as per Paris MoU	
7) Incentive System for good ships:	no		no		no	
Inspection Systems and References to IMO Resolution A.466(XII), A.787(19) and A.822(21)						
References to IMO Resolutions	A.787(19) for Marpol A I&II		A.682(17), A.787(19)		A.682(17), A.787(19), A,822(21)	
Priority inspections	yes		yes		yes	
Initial inspections	yes		yes		yes	
More Detailed inspection if clear grounds	yes, clear grounds defined		yes, clear grounds defined		yes, clear grounds defined	
Expanded inspection	yes		no		no	
Re-examination/Follow up inspections	not stated		not stated		not stated	
Remedies for no compliance	detention		detention		detention	

Source: Compiled by author from MoU's, IMO Resolutions and interviews

Table 2 continued	Indian Ocean MoU		AMSA*)		US Coast Guard	
Memorandum Signed/Take Effect	**1998**		**n/a**		**n/a**	
Years in Existence as per 2005	**7**		**n/a**		**n/a**	
Relevant Instruments	**Convention**	**Protocols**	**Convention**	**Protocols**	**Convention**	**Protocols**
1) Load lines 66 & Protocol 88	yes	not specified	yes	yes	yes	yes
2) SOLAS 74 & Protocols 78 & 88	yes	not specified	yes	yes	yes	yes
3) MARPOL 73/78 with Protocol 78 & 97	yes	yes	yes	not Annex VI	yes	not Annex IV and VI
4) STCW 78 & Amendments of 95	yes	n/a	yes	n/a	yes	n/a
5) COLREG 72	yes	n/a	yes	n/a	yes	n/a
6) TONNAGE 69	yes	n/a	yes	n/a	yes	n/a
7) ILO Conv. Nr. 147, 1976 & Prot.96	yes	not specified	not ratified	not ratified	yes	not ratified
8) The Intern. Conv. on Civil Liability for Oil Pollution Damage, 1992 Protocol.	not specified	not specified	n/a	yes	not ratified	n/a
9) Treatment for ships flying a flag not party to the legal instruments	no favorable treatment		no favorable treatment		no favorable treatment	
10) Other Legal Instruments	not relevant		Tokyo MoU and Indian Ocean MoU, Austr. Navigation Act 1912 section 190AA and 210		Title 46 US Code (Ch33), OPA 90, MTSA 02	
Targeting System						
1) Amount of ships to be inspected:	at least 10% of estimated number of foreign ships		minimum of 50% of eligible ships defined under point 4)		not relevant	
2) Variables used for targeting:	ships suspended from class for safety reasons within preceding 6 months		target factor based on ship risk profiles (probability of detention)		based on management, flag, class, ship type and vessel history of the area	
3) Targeted ship types either by type/age or size:	ships carrying dangerous cargos and failed to report information to authorities		bulk carriers due to the high % of bulk carriers arriving in Australia		oil and chemical tankers, gas carrier, bulk, passenger ship, general cargo	
4) Time criteria	if entering area for the first time or absent of 12 months		cargo ships every 6 mts, tankers over 15 yrs and passenger ships every 3 mts		yes, built into the matrix	
5) Quantitative Target Factor:	no quantitative system		yes - based on a risk factor on arrival (probability of being unseaworthy)		yes, different boarding priorities according to points	
6) Deficiency Coding	coding as per Paris MoU		coding as per Paris MoU		different coding but recoding made for Equasis	
7) Incentive System for good ships:	no		no but charges for more detailed inspections - AD 185/hr		yes, Qualship 21	
Inspection Systems and References to IMO Resolution A.466(XII), A.787(19) and A.822(21)						
References to IMO Resolutions	A.682(19), A.787(19)		A.787(19), A.822 (21)		A.787(19)	
Priority inspections	yes		yes		yes	
Initial inspections	yes		yes		yes, annual examination	
More Detailed inspection if clear grounds	yes, clear grounds defined		yes, clear grounds defined		yes, clear grounds defined	
Expanded inspection	no		no		no, more expanded examinations are more detailed inspections	
Re-examination/Follow up inspections	not stated		yes, follow up on deficiencies		yes, follow up inspections	
Remedies for no compliance	detention		detention, for non-compliance to Sect. 190AA of the Navigation Act, fines can be imposed		detention, for non-compliance to US law - civil penalty action	

*) *AMSA is part of the Indian Ocean MoU and the Tokyo MoU but is treated individually in this analysis*

The regimes were compared based on their legal relevant instruments for inspection on foreign vessels, their targeting system and the inspection systems including the deficiency coding and detentions and a detailed list of these findings is given in Table 2 for easier comparison. The historical development of the regimes varies which can easily be seen by the number of years of existence. The USCG started with its inspection program in a limited version in 1968[27] for passenger vessels and expanded the program to all vessels calling US ports with the 1978 Port and Tanker Safety Act. After the accident of the Exxon Valdez in 1989 and the creation of the Oil Pollution Act (OPA 90), inspection on foreign vessels were re-enforced and clear guidelines of the requirements to comply with US law were given. As the world fleet changed in the composition of flags and the US became primarily a port state, it started to emphasize on developing a targeting matrix for foreign flagged vessels and implemented the PSC program in 1994.

2.1.2. The Relevant Legal Instruments across the Regimes

The relevant legal instruments are listed in Table 2. In essence, there are some differences in the legal instruments across the MoU's but all regimes do not give favorable treatment to ships flying a flag which is not a party to the international conventions. The Paris MoU area, the US Coast Guard and AMSA have other legal instruments besides the international conventions which are added or replace some of the international conventions. The Caribbean Memorandum refers to the Code of Safety for Caribbean Cargo ships (CCSS Code) for ships below 500 gt and the USCG also acknowledges the application of this code for the eligibility of inspections for vessels trading to U.S. ports (7th district)[28] but below 500 gt. For failure to comply to US law, the US Coast Guard can respond with civil action or criminal proceedings which are a very strong incentive to comply for ship owners. AMSA based on the Australian Navigation Act can impose fines. For the EU area, due to the European Court of Justice and its power to start legal proceedings against its flag and port states, the incentive to comply is also much stronger than in the other regions and new legislative developments in the EU area should further enhance enforcement in the future.

2.1.3. Targeting Systems and Deficiency Coding

Some port state control regimes use custom made target factors to decide if a vessel should be inspected or not since available resources should be allocated to inspect high risk vessels. Those target factors might reflect the regional needs since port state control is linked to the trade flows which determine the ship types. All regimes target certain ships types and use a time criteria and the history of previous inspections as an input variable. The regimes do not take inspections of each other into consideration. The Paris MoU, the US Coast Guard and AMSA[29] have a quantitative system which ranks ships in the order of risk and determines if certain ships have to be inspected if a certain risk level is reached. The other regimes might have an internal target factor in place but enforcement is not guaranteed by the memorandum. The deficiency codes are more or less synchronized with the deficiency codes used by the Paris MoU with the exception of the USCG who uses its own deficiency coding. For the purpose of this analysis, the deficiency

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[27] USCG Port State Control Speech, http://www.uscg.mil/hq/g-m/pscweb/psc_speech.pdf

[28] the USCG inspection coverage is divided into districts

[29] In this respect, it is worth noticing, that AMSA has already used similar econometric techniques in 2002 in order to determine targeting of vessels for inspections and has also implemented the findings into practise in 2003. The administration has evaluated the implementation and believes that it has been successful in detecting sub-standard vessels. It is currently reviewing the system to further enhance it.

codes were re-classified by the USCG to fit into the Paris MoU deficiency codes. A full list of the codes is provided in Table 3. Not all codes are used in the analysis since for instance code 2700 is related to security which is not part of this thesis. The two miscellaneous codes 9800 and 9900 where also left out in most of the regressions.

2.1.4. Inspection Systems and Remedy for Non Compliance

Some regimes partly refer to IMO Resolution A.787(19) for operational procedures either to define clear grounds, inspections procedures or grounds for detention which was amended by Resolution A.822(21) incorporating the ISM Code. All regimes divide between priority inspections, initial inspections and more detailed inspections in case of "clear grounds".

Table 3: Description of Main Deficiency Codes

Code	Deficiency Code Description	Code	Deficiency Code Description
100	Ship's certificates and documents	1600	Radio communications
200	Crew certificates	1700	MARPOL Annex I (Oil Pollution)
300	Accommodation	1800	Gas and chemical carriers
400	Food and catering	1900	MARPOL Annex II (Noxious Liquids)
500	Working spaces & accident prev.	2000	SOLAS Operational deficiencies
600	Life saving appliances	2100	MARPOL related oper. deficiencies
700	Fire Safety measures	2200	MARPOL Annex III (Pack.Harmf.Sub.)
800	Accident prevention (ILO147)	2300	MARPOL Annex V (Garbage)
900	Structural Safety	2500	ISM related deficiencies
1000	Alarm signals	2600	Bulk carriers
1100	Cargoes	2700	Security (ISPS Code)
1200	Load lines	2900	MARPOL Annex IV (Sewage)
1300	Mooring arrangements (ILO 147)	9800	Other def. clearly hazardous safety
1400	Propulsion & auxiliary engine	9900	Other def. not clearly hazardous
1500	Safety of navigation		

The definition of clear grounds can vary across the regimes but not significantly and covers in essence the power of the officer to conduct a more detailed inspection if he/she feels that it is necessary an in particular, if the crew onboard is not familiar with the safe operation of the vessel. Guidance on clear grounds and a list of detainable deficiencies as defined by the IMO guidelines (Resolution A.787(19)), Chapter 2.3 are as follows[30]:

1. *the absence of principal equipment or arrangements,*
2. *ship's certificates are clearly invalid,*
3. *certificates are incomplete, not maintained or falsely maintained,*
4. *evidence from general impression and observation reveals serious hull or structural deterioration that may place at risk the structural, watertight or weather tight integrity,*
5. *evidence from general impression and observation reveals serious deficiencies in the area of safety, pollution prevention or navigational equipment,*
6. *master or crew is not familiar with essential shipboard operations relating to the safety of ships or the prevention of pollution,*
7. *key members cannot communicate with each other,*
8. *emission of false distress alerts followed by proper cancellation procedures,*
9. *receipt of a report of complaint containing information that the ship is substandard*

[30] based on IMO guidelines for PSC, Resolution A.787(19), chapter 2.3

For the USCG, the more detailed inspection is called expanded examination. In the Paris MoU area, the expanded inspections are a unique concept and apply to oil tankers[31] (> 3000 gt and > 15 years), bulk carriers (> 12 years), passenger ships (> 15 years) and gas and chemical tankers (> 10 years). This type of inspection is based on the EU Council Directive 106/2001/EC which is currently under review (port state control directive) and is therefore only applicable for the Paris MoU members. Follow up is specified within the US Coast Guard Regime and AMSA.

2.1.5. The Definition of a Substandard Vessel

The circumstances leading to a detention is defined in all MoU's and in all cases, detention is justified, if the ship is to be seen as substandard. A list of detainable deficiencies can be found in Appendix 2 for further reference. The guidelines provided by the IMO PSC procedures for the identification of a substandard vessel and which is also in adapted form used by the USCG are as follows:[32]:

"A ship is regarded as substandard if the hull, machinery, or equipment, or operational safety, is substantially below the standards required by the relevant conventions or if its crew is not in conformance with the safe manning document, owing to, inter alia:

1. *The absence of required principal equipment or arrangement.*
2. *Non-compliance of equipment or arrangement with relevant specifications.*
3. *Substantial deterioration of the ship or its equipment.*
4. *Insufficient operational proficiency, or unfamiliarity of the crew with essential operational procedures.*
5. *Insufficiency of manning or insufficiency of certification of seafarers.*
6. *Noncompliance with applicable operational and/or manning standards;*

If these evident factors as a whole or individually make the ship unseaworthy and put at risk the ship or the life of persons on board or present an unreasonable threat of harm for the marine environment if it were allowed to proceed to sea, it should be regarded as a substandard ship".

2.1.6. The Importance of Ship Types and Trade Flows

The division of ship types is crucial for this analysis for various reasons. First, the legal base which is the basis for the port state control inspections clearly distinguishes the ships types and second, port state control is influenced by the trade flows as they determine the ship types that will visit a particular country of a regime. The decision factors taken into consideration to divide the datasets per ship types are given in Figure 6 and can be summarized 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.
- *Point 3:* Analysis of Casualties per ship type and their severity.
- *Point 4:* Correspondence analysis to provide an overall confirmation on the selection of the grouping of ship types with respect to the port state control deficiencies.

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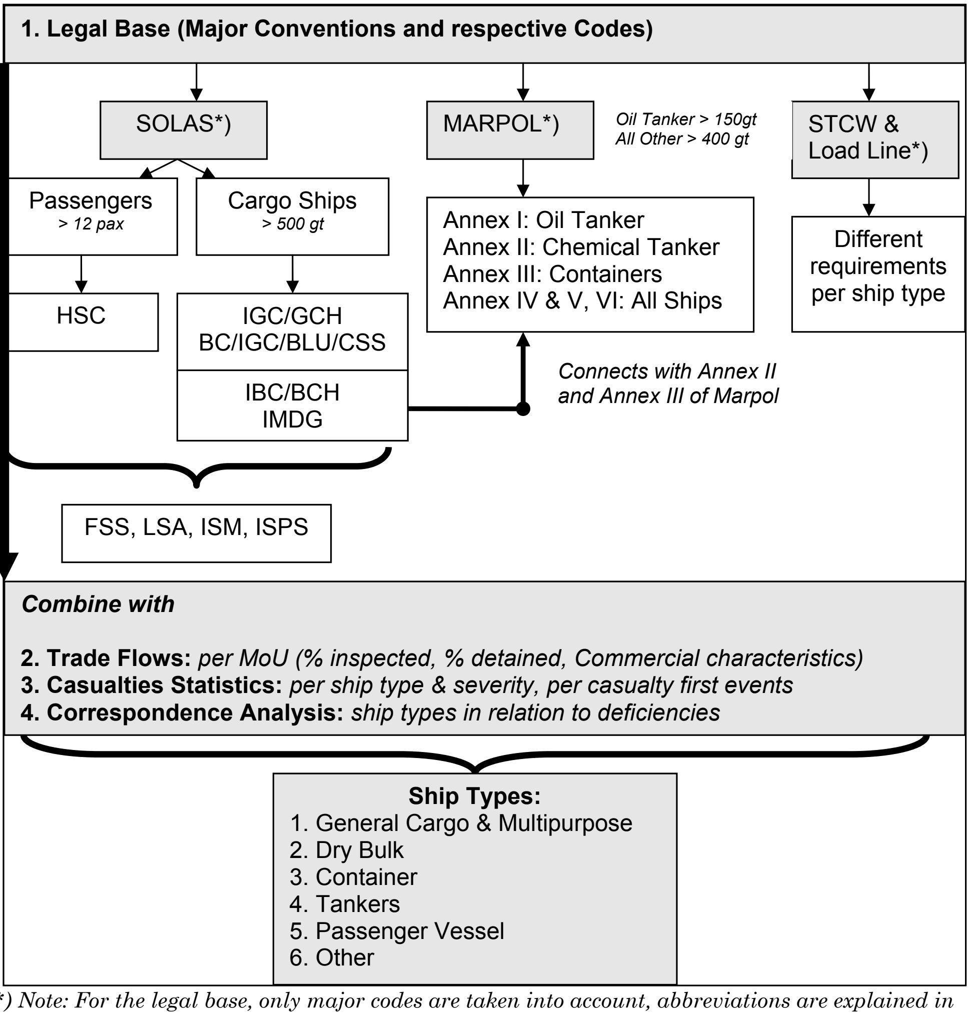
[31] Paris Memorandum of Understanding, Annex I, page 38

[32] IMO Resolution A.787(19), Chapter 4 and USCG Marine Safety Manual, Vo. II, Section D, page D1-5

While point 1 and 2 is explained in detail here, the rest is presented in later chapters of this thesis when the variables used to perform these analyses are explained in detail. The casualty analysis is shown in Chapters 5 while the Correspondences Analysis is treated under Chapter 3 where ship types and deficiencies are correlated.

Figure 6: The Selection of Ship Types



**) Note: For the legal base, only major codes are taken into account, abbreviations are explained in the following text to come*

The three most important conventions and amendments create a different operating environment for ship types. Sometimes, age and size of a vessel determines application of regulations within the ship types. Depending on the convention or code, exact definitions of ship types are provided and can be found in Appendix 3 for further detail. In general, the following items underline the decision to split up the ship types.

SOLAS (Safety of Life at Sea)[33]

SOLAS is for the requirements of construction of a vessel and all items related to the safety of life at sea. It divides between passenger and cargo ships. It applies to all ships above 500 gt on international voyages. Passenger ships are ships exceeding 12 passengers and all other ships are cargo vessels. SOLAS refers to several codes which can be particular to certain ship types as follows:

- HSC – International Code of safety for high-speed craft (for ships built after January 1996),
- IGC – International Code for the construction and Equipment of Ships Carrying Liquefied Gas in Bulk (for ships constructed after 1st October 1994,
- GCH – Old Gas Carrier Code for ships constructed before 1st October 1994 as per resolution MSC 5 (48),
- BC – Code of safe practice for solid bulk cargoes,
- BLU – Code of practice for the safe loading and unloading of bulk carriers,
- CSS – Code of safe practice for cargo stowage and securing,
- IBC – International Code for the Construction and Equipment of ships carrying dangerous chemicals in bulk (for ships constructed after 1st July 1986),
- BCH – Code for the construction and equipment of ships carrying dangerous chemicals in bulk (for ships constructed before 1st July 1986),
- IMDG – International Maritime Dangerous Goods Code: contains classification, packing, marking, labeling and stowage of dangerous goods in packaged form – mainly Containers,
- FSS – Fire Safety Systems Code: Can have specific requirements of fire fighting equipment per ship type,
- LSA – International Life Saving Appliance Code: can have specific life saving appliances equipment depending on the ship type,
- ISM – International Safety Management Code and ISPS – International Code for security of ships and of port facilities.

MARPOL (Prevention of Pollution from Ships)[34]

- General Application: all ships but surveys (Regulation 4) only apply to oil tankers above 150gt and all other ships above 400 gt.
- Annex 1: Oil Pollution - Ship Type: All ships but in particular oil tankers.
- Annex 2: Noxious Liquids in bulk - Ship Type: Chemical Tankers and link to IBC Code.
- Annex 3: Harmful Substances in Packaged Form – Ship Types: Containers and link to IMDG Code.
- Annex IV (Sewage) and Annex V (Garbage): applies to all ships with some size restriction on certification requirements.
- Annex VI (Air Pollution): applies to all ships with certain size restriction on certification requirements.

STCW (Standard Training and Watchkeeping)[35] ***and LL (Load Lines)***

STCW applies to all seagoing ships not engaged on national voyages and lists the crew certification requirements. Requirements can vary by ship type (tankers, chemical tankers, gas carriers) – e.g. special requirements for tankers for cargo operations and fire fighting, pollution prevention. The load line convention applies to all ships engaged on international voyages. It provides different requirements based on ship types and vessel

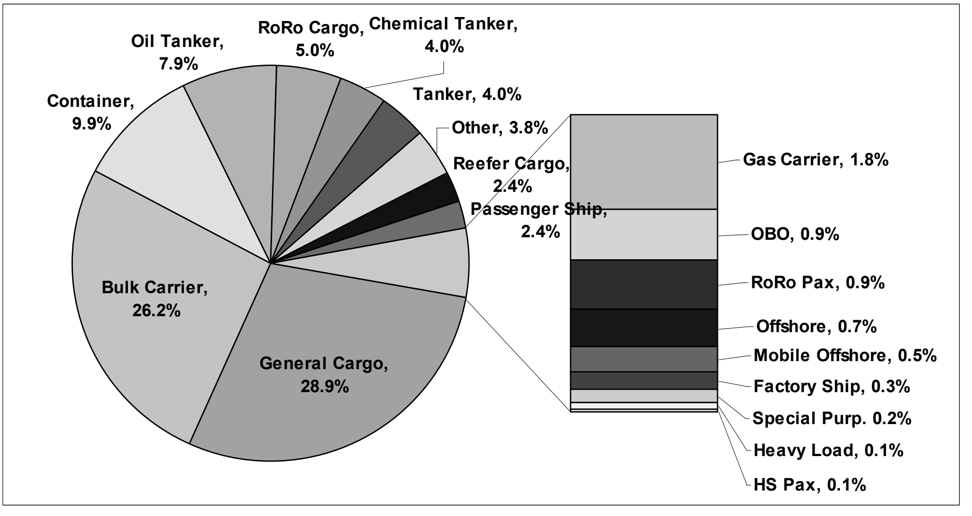
[33] International Convention for the Safety of Life at Sea, 1974 and Protocols 1978 and 1988, IMO

[34] International Convention for the Prevention of Pollution form Ships with Annexes I to VI, IMO

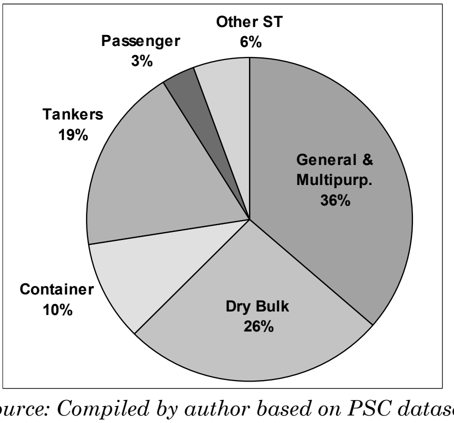
[35] International Convention on Standards of Training, Certification and Watchkeeping for Seafarers, 1978 and International Conventions on Load Lines, 1966

age and size. The resulting ship types can be seen in Figure 7 before and after regrouping. Containers are part of general cargo but more sophisticated and although the port states control inspection of a general cargo ship does not significantly differ from a container ship, due to the different commercial setup of the two segments, the container ship is kept separate from the rest of the general cargo ships. In addition, Annex II of MARPOL refers to Container Ships due to the IMDG Code (Stowage of dangerous goods in packaged form).

Figure 7: Ship Types Inspected (Before and After Regrouping)



After Regrouping

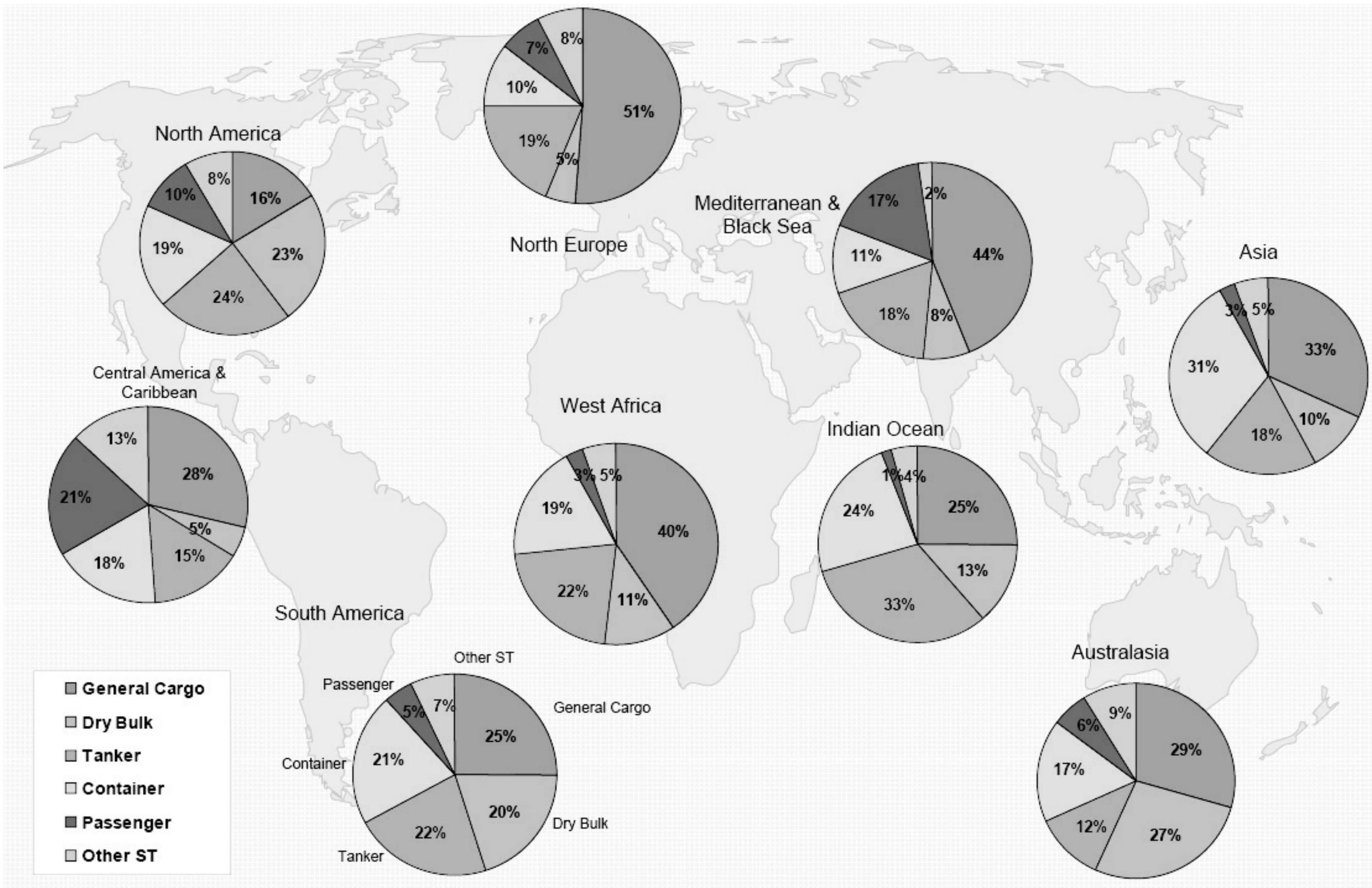


Source: Compiled by author based on PSC dataset

Figure 8 provides an overview of the trade flows based per number of port calls and split up per ship type for the year 2004 while Figure 9 provides the same information based on average billion ton-miles[36] shipped across the globe for the major commodities. Both figures provide an overview of the major trade flows and how they affect the port state control areas.

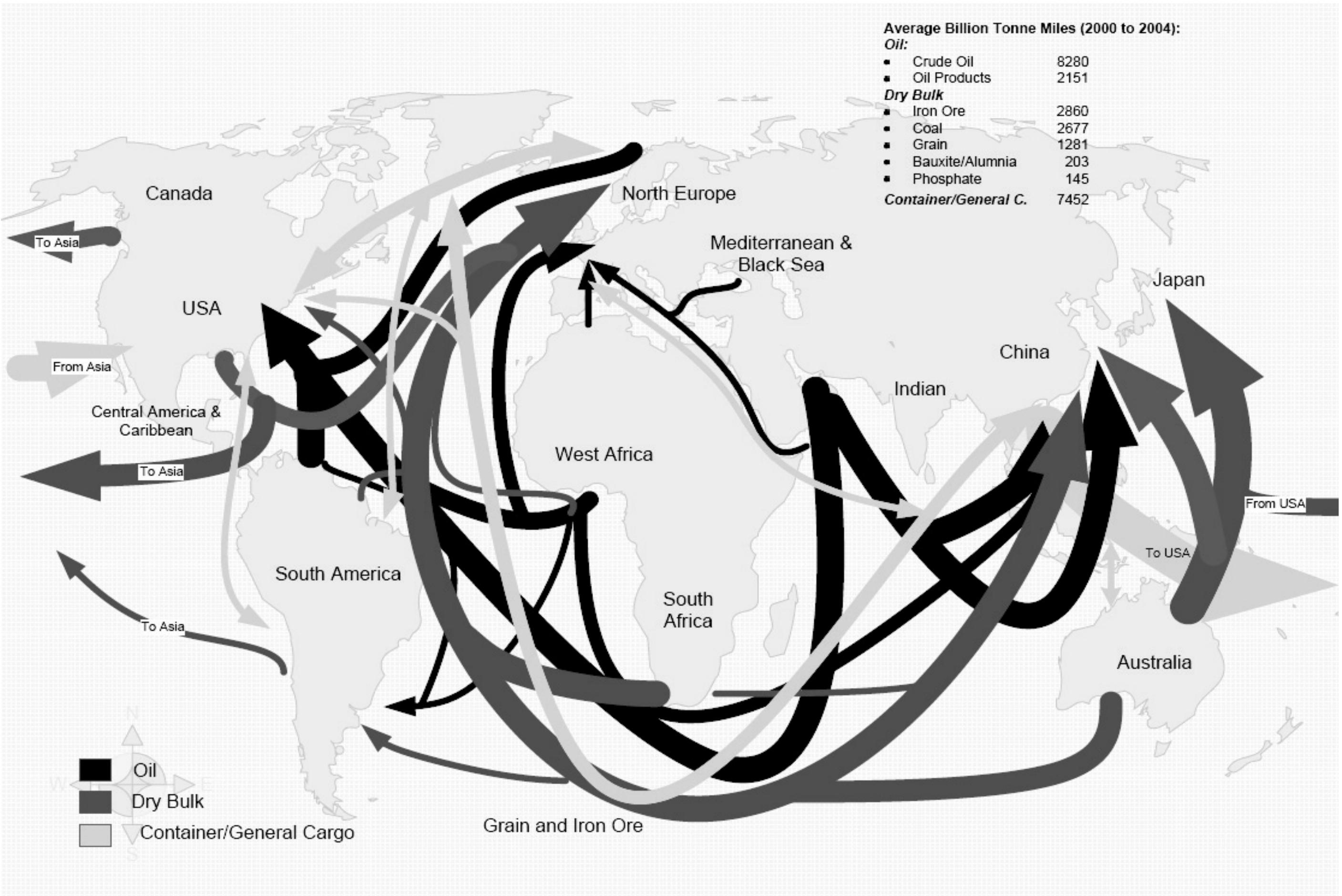
[36] Tonnage of cargo shipped times average distance transported

Figure 8: Overview of Trade Flows (Port Calls per Ship Type, 2004)



Based on Data from LMIU (Lloyd's Maritime Atlas of World Ports and Shipping Places, 2004)

Figure 9: Major Trade Flows (Average Million Ton-Miles for 2000 to 2004)



Based on Data compiles from Fearnley's and ISL (Institute of Shipping Economics and Logistics)

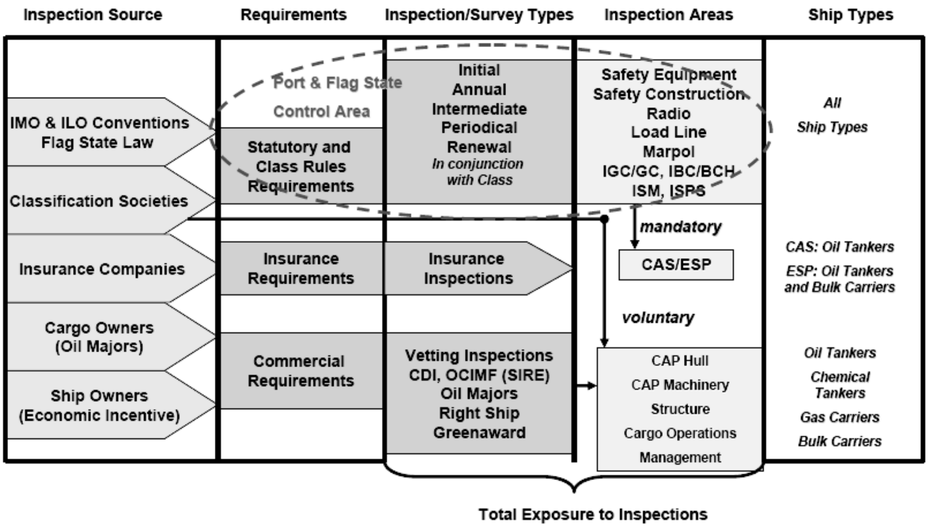
2.2. The Total Exposure to Inspections

2.2.1. Overview of Inspections in the Name of Safety

The following section will provide a short overview of the different kind of inspections and surveys that are carried out on ships besides port state control inspections. An overview of the total exposure to inspections is given in Figure 10. The inspections originate from various sources and are as follows:

- Port state control inspections and flag state control inspections.
- ISM and ISPS audits due to statutory requirements and which are still sometimes performed by the flag states but most of the time also delegated to recognized classification societies.
- Classification surveys on behalf of flag states and to remain in class[37].
- Insurance companies such as P&I Clubs for insurance coverage purposes.
- Industry inspections such as vetting inspections performed on oil tankers, chemical tankers, gas carriers and bulk carriers on behalf of oil majors or other cargo owners or on behalf of the ship owner. (CDI, OCIMF/SIRE, Rightship, Oil Majors).
- Commercial incentives: These inspections are on request of the ship owner in order to obtain a quality certificate which will then help in obtaining commercial incentives.

Figure 10: Summary of Total Inspection and Audit Exposure[38]



Source: compiled by author from various legal sources and inspections

2.2.2. Mandatory Inspections/Surveys/Audits

Port state control and flag state inspections cover the statutory requirements. Classification societies perform most of the surveys based on the statutory requirements and by authorization of a flag state. The IMO has tried to synchronize the various types of

[37] a ship does not necessary have to be in "class" in order to trade but it is highly recommended.
[38] Note: CAS = Condition Assessment Scheme, ESP = Enhanced Survey Program, CAP = Condition Assessment Program

inspections and in essence, four types of mandatory inspections can be identified and are shown in the graph which covers the inspection areas listed next to the inspection types. Depending on the type of survey (e.g. initial, annual, renewal, etc.) the content and intensity of the inspection areas is changed accordingly. An initial survey is a complete inspection before the vessel comes into service. In addition to the mandatory inspection types and areas, two mandatory survey programs are identified and are also normally provided by the classification societies. The first one is *CAS* (Condition Assessment Scheme) based on MARPOL and the second is the *ESP* (Enhanced Survey Program) based on SOLAS.

The Condition Assessment Scheme originated from an amendment to Annex I of MARPOL Annex I (Regulation 13G) and can be applied to single hull tankers above 15 years of age. It is intended to complement the requirements of the Enhanced Survey Program of SOLAS which applies to bulk carriers and oil tankers. Both require a different scope of survey depending on the age of the vessel including thickness measurements and rate the coating conditions of the tanks as GOOD, FAIR and POOR which is sometimes important information for vetting inspections.

To facilitate the various mandatory inspections/survey types shown in Figure 10 and which need to be carried out, the IMO established the “Harmonized System of Survey’s and Certification” which can be seen in summarized version in Table 4[39] where the following abbreviations are used[40]:

- *A – Annual:* general inspection of the items relating to the certificate to ensure that they have been maintained and remain satisfactory for the service for which the ship is intended.
- *P – Periodical or I - Intermediate:* inspection of the items related to the certificate in order to ensure that they are in satisfactory conditions and fit for the service for which the ship is intended. It is a more detailed inspection compared to the annual inspection and is called periodical with reference to the radio equipment and intermediate for all other types of surveys.
- *R – Renewal:* same as periodical but more detailed and leads to the issue of a new certificate and normally involves dry docking.

Table 4: Summary of Harmonized System of Survey and Certification

Years	**1**			**2**			**3**			**4**			**5**	
Months	**9**	**12**	**15**	**21**	**24**	**27**	**33**	**36**	**39**	**45**	**48**	**51**	**57**	**60**
Certificates/Inspection Areas														
Passenger Ship Safety Cert.	R			R			R			R			R	
CS Safety Equipment Cert.	A			A or P			P or A			A			R	
CS Safety Radio Certificate.	P			P			P			P			R	
SC Safety Construction Cert.	A			A or I			I or A			A			R	
CF Gas (IGC/GC)	A			A or I			I or A			A			R	
CF Chemical (IBC/BCH)	A			A or I			I or A			A			R	
Load Line Certificate	A			A			A			A			R	
IOPP (MARPOL Annex I)	A			A or I			I or A			A			R	
IPP (MARPOL Annex II)	A			A or I			I or A			A			R	

Based on IMO Resolution A 746 (18)
Abbreviations: CS = Cargo Ship, CF = Certificate of Fitness, IOPP = Intern. Oil Prevention Pollution Certificate, IPP = Intern. Pollution Prevention Certificate for Carriage of Noxious Liquid Substances in Bulk

[39] Extract from IMO Resolution A 746 (18), page 246 and amendment
[40] Based on IMO Resolution A.746 (18), page 151 and amendment

The table shows the time periods and within which time periods the different types of surveys can be conducted. It allows a harmonized approach between the various SOLAS and MARPOL requirements. Passenger vessels have to follow stricter survey schemes (renewal surveys) than other ship types and a renewal survey has to be carried out each year versus every five years. Intermediate surveys come into the picture between the 2nd and 3rd year in order to decrease the inspection time required for a full renewal survey.

Besides the items listed above, two types of audits are identified in Figure 10 - the *ISM* (International Safety Management) audit and the *ISPS* (International Ship and Port Security) audit which are both SOLAS requirements. This certification is split into a shipboard part and a company part where the shipboard part has to be completed every five years with one intermediate audit half way). Some flag administrations have not yet authorized classification societies to perform these audits but many flag states have done so and this area is therefore also widely covered by classification societies.

2.2.3. Non Mandatory Inspections

Cargo owners have considerable power through their vetting inspections for certain ship types (oil tankers, chemical tankers, gas carriers and dry bulk carriers). Sometimes these inspections originate from the cargo owner or sometimes the ship owner will ask for the inspection in order to show a certain quality level for a potential cargo owner. Going through an inspection does not necessarily mean the ship is accepted for cargo. It becomes clear from the graph that the targeted ship types are chemical tankers, oil tankers, gas carriers and bulk carriers for the industry inspections while inspections based on statutory requirements are valid for all ship types. The various inspection systems do reference each other but there is no cross-recognition. The following paragraphs will describe the systems further.

CDI (Chemical Industry Institute): CDI inspections originate from the ship owner and are therefore owned and paid by the ship owner. The owner requests a CDI inspection and the inspector is appointed to the vessel. Inspections are based on a standardized questionnaire covering all areas of shipboard operations and are split up into "statutory requirements" (based on the international conventions), "required" (as per industry Code of Practice) and "desired" (required by CDI participants or users of the reports) requirements. An inspection normally takes around 8-10 hours where particular emphasis is placed on cargo operations and the competence of crew. CDI inspections are primarily performed on chemical tankers. After the inspection, the report is uploaded to the CDI system and the ship owner can provide comments to the inspection results. After that, the ship owner can decide if the report goes alive or not and becomes visible for the CDI users.

***SIRE (Ship Inspection Report Program) and inspection from Oil Majors*:** Sire inspections are performed by OCIMF (Oil Companies International Marine Forum) and originate from cargo owners. The inspectors are appointed by OCIMF and the information is however owned by the cargo owner but partly made available to other OCIMF members who can obtain parts of the inspection results for a fee. The inspections also cover more or less the same areas as CDI with a heavy influence on cargo operations and can take 8 to 10 hours. Ship Owners have some time to comment to the issued report before it becomes available online. These types of vetting inspections are primarily for oil tankers. While the standardized questionnaire serves as a basis, some oil majors have additional requirements and will add these requirements during an inspection which can be confusing for the ship owners and their crew since no split between statutory requirements and other requirements is made. In addition, oil majors normally perform their own inspections where the basic requirements are according to the SIRE inspections but additional requirements per oil major are added to the inspection and are not published in the SIRE report.

Rightship: Rightship is a ranking system which combines information obtained through vetting inspections, port state control, casualties, ship particular information and ship owner information. It ranks vessels according to a rating score (1 to 5 stars where 5 stars represents a very good vessel with low risk). It is based on a joint venture between BHP Billiton Freight Trading and Logistics and Rio Tinto Shipping. The inspections cover tankers and bulk carriers but are primarily for dry bulk carriers. A Rightship Inspection can take from 8 to 48 hours and covers all aspects of shipboard operations in addition to ship structure and cargo handling equipment including hatch covers which is important for dry bulk carriers. Inspectors perform ballast water tank inspections and evaluate the conditions of the cargo holds.

Greenaward: The last kind of inspection that is performed on vessels (oil tankers) originates from the Greenaward Foundation. These inspections are paid by the ship owner. An initial inspection will take approx. 9 hours and cover all aspects of shipboard operations. In addition to the shipboard audit, an office audit (2 days) is performed to evaluate the shore based management systems and support to the vessels. After successful completion, the ship receives a certificate (Greenaward) and the ship owner can obtain discounts on harbor dues from ports participating in the program. Once the vessel is "Greenaward Certified", it needs to undergo annual or intermediate surveys to remain certified. The Greenaward Foundation is a non-profit foundation. Over the years, the Greenaward Certificate is not yet officially recognized by port state control regimes. The approach is more complete and includes shore-side and ship-side elements of the operations.

In addition to the statutory requirement for CAS and the ESP, some oil majors ask a ship owner to participate in *CAP* ***(Condition Assessment Program)*** for either hull or machinery. Those programs are offered by classification societies and are purely voluntary and provide the ship owner with a rating (CAP 1, 2 or 3 where CAP 1 represent the best rating) which is important for some oil majors. There is an overlapping of CAP with CAS where the main difference is that CAS is a statutory requirement and its end users are the flag states while CAP is a voluntary program required by oil majors who decides on the minimum of the CAP rating.

2.2.4. Comparison of Inspection Areas

The next section will provide a comparison between the various inspections (excluding ISPS) that are performed on the vessels and explained previously. It will only concentrate on inspections performed on ships and only highlight the main areas and items that are inspected in comparison with each other. The inspection matrix can be seen in Table 5 for easier reference and was compiled based on the experience the author collected by observing some inspections and the check-lists of some of the inspectors. The legend and color coding for the table is provided here below:

x	= part of inspection round
r	= referenced during inspection
i	= actual physical inspection/testing/interviews
s	= depends on situation, for class on the type of survey (annual, intermediate, renewal)

Table 5: Inspection Matrix - Main Areas of Inspection in Comparison

Note: Compiled by author				Party performing the inspection/survey/audit								
Inspection Matrix - Main Areas of Inspection	**Source of Inspection**			**Port & Flag State or Class**				**Industry**				
	International Conventions (statutory)	**Flag State**	**Add. Industry Requirements**	**Port State (more detailed insp.)**	**Flag State**	**Class Surveys**	**ISM (emphasis on the system)**	**Insurance (P&I Clubs)**	**CDI/OCIMF**	**Rightship**	**Greenaward (Shipside Part)**	**Ship Crew Involved**
	Average Time onboard (hrs.)			**6-8**	**8**	**24-48**	**8**	**8**	**8-10**	**8-48**	**9**	
Registration & Administration (Certificates)												
Statutory Certificates	various	x		r	r		r	r	r	r	r	Master, Chief Officer
Crew Certificates (plus Endorsements)	SOLAS/STCW	x		r	r		r	r	r	r	r	
Crew Nationality			x							r		
Medicals		x		r	r		r	r	r	r	r	
Other Certificates for Equipment Testing	various	x		r	r		r	r	r	r	r	
Previous Port State Control/Flag State Reports			x		r		r	r	r	r	r	
Vetting Inspection Reports			x							r	r	
Living and Working Conditions												
Accommodation	ILO	x		x	x			x	x	x	x	Chief Officer, Third Officer, Cook
Food (Inspection of Freezers and Galley)	ILO	x		x	x			x	x	x	x	
Living Conditions/Public Spaces	ILO	x		x	x			x	x	x	x	
Rest Periods and Watch Keeping Hours	STCW	x		r	r		r	r	r	x	r	
Safety Signs, Protection Equipment	SOLAS			x	x	x	x	x	x	x	x	
Gas Detection and Calibration	SOLAS/ISM			x	x	i	x	x	x	x	x	
Decontamination showers and eyewash on deck	SOLAS/ISM			x	x	i	x	x	x	x	x	
Mooring Arrangements Safe & Maintained	SOLAS/ISM	x		x	x	x	x	x	x	x	x	
Hospital and Medical Attention		x		x	x	x	x	x	x	x	x	

Note: Compiled by author

Inspection Matrix - Main Areas of Inspection	Source of Inspection			Party performing the inspection/survey/audit								
				Port & Flag State or Class				Industry				
	International Conventions (statutory)	Flag State	Add. Industry Requirements	Port State (more detailed insp.)	Flag State	Class Surveys	ISM (emphasis on the system)	Insurance (P&I Clubs)	CDI/OCIMF	Rightship	Greenaward (Shipside Part)	Ship Crew Involved
Management ISM												
Safety Management System/Master's Authority	SOLAS/ISM	x		r	r		i	r	r	r	i	Master, Chief Officer, Third Officer
Safety & Environmental Policy	SOLAS/ISM	x		r	r		i	r	r	r	i	
DoC Company and Designated Person Ashore	SOLAS/ISM	x		r	r		i	r	x	r	i	
Company Internal Audits	SOLAS/ISM	x		r	r		i	r	x	r	i	
Records of Incidents/Near Misses/Accidents	SOLAS/ISM	x		r	r		i	x	x	r	i	
Maintenance Routines, Non-conformities	SOLAS/ISM	x		r	r		i	r	x	r	i	
Operational Safety - Safety Procedures (Hot Work, Entry into enclosed spaces)	SOLAS/ISM	x		r	r		i	r	r	r	i	
Safety, Fire and Abandon Ship Drills	SOLAS/ISM	x		i(s)	i(s)		r	r	x	r	i	
Onboard Communication satisfactory				x	x		x	x	x	x	x	
Crew Familiarization	ISM	x			x		i	r	x	i	x	
Company Drug and Alcohol Policy and Testing			x					r	x	r	x	
Crew Working Experience			x						x	i	x	
Manning and Training Policy			x					r	x	i	x	
Security Related Items	SOLAS/ISPS			x	x				x	x	x	
Safety and Fire Appliances												
SOLAS Training Manuals	SOLAS	x		x	x	x	x	x	x	x	x	Chief Officer, Third Officer
Muster Lists and Emergency Instructions	SOLAS	x		x	x	i	x	x	x	x	x	
Lifesaving Appliances (Lifejackets, Immersion Suits, etc)	SOLAS	x		i	i	i	x	i	i	x	x	
Lifeboat, Life rafts, Equipment and Launching	SOLAS	x		i	i	i	x	i	i	x	x	

Note: Compiled by author

Inspection Matrix - Main Areas of Inspection	Source of Inspection			Party performing the inspection/survey/audit: Port & Flag State or Class				Industry				
	International Conventions (statutory)	Flag State	Add. Industry Requirements	Port State (more detailed insp.)	Flag State	Class Surveys	ISM (emphasis on the system)	Insurance (P&I Clubs)	CDI/OCIMF	Rightship	Greenaward (Shipside Part)	Ship Crew Involved
Rescue Boat and equipment	SOLAS	x		x	x	i	x	x	x	x	x	
Pilot Ladder, Embarkation Ladders for Lifeboats	SOLAS	x		i	i	i	x	i	i	x	x	
Oxygen & Acetylene Storage, CO2 room	SOLAS	x		i	i	i	x	i	i	x	x	
Fire Control Plan	SOLAS	x		r	r	i	x	r	r	r	r	
Fire Fighting Equipment and Detection	SOLAS	x		i	i	i	x	i	i	x	x	
Fireman's outfit, breathing apparatus, air bottles, EEBD	SOLAS	x		x	x	i	x	x	x	x	x	
Fire/Foam Hydrants	SOLAS	x		x	x	i	x	x	x	x	x	
Industry Guidelines/Publications			x					x	x	i	x	
Navigation and Communication												
Company Navigation Procedures	STCW	x		x	x	x	x	x	x	x	x	Chief Officer, Second Officer
Bridge Standing Orders	SOLAS	x		x	x	x	x	x	x	x	x	
Passage Planning	STCW	x		x	x	x	x	x	x	x	x	
Chart Corrections	SOLAS	x		x	x	x	x	x	x	x	x	
Nautical Publications up to date	various	x	x	x	x	x	x	x	x	x	x	
Navigational Equipment Working (GPS, Speed Log, Radar, Echo Sounder, Compass, Navtex etc.)	SOLAS	x		x	x	i	x	x	x	x	x	
Dead man Alarm (when applicable)		x		x	x	x	x	x	x	x	x	
Guidelines for the prevention of fatigue			x							r		
Crew knows how to operate equipment	STCW	x		x	x	x	x	x	x	x	x	
VDR/AIS	SOLAS	x		x	x	i		x	x	x	x	
Compass Error Log	STCW	x		x	x	x		x	x	x	x	

Note: Compiled by author

Inspection Matrix - Main Areas of Inspection	Source of Inspection			Party performing the inspection/survey/audit: Port & Flag State or Class				Industry				
	International Conventions (statutory)	Flag State	Add. Industry Requirements	Port State (more detailed insp.)	Flag State	Class Surveys	ISM (emphasis on the system)	Insurance (P&I Clubs)	CDI/OCIMF	Rightship	Greenaward (Shipside Part)	Ship Crew Involved
Compass Deviation Card	SOLAS	x		x	x	x		x	x	x	x	
Navigation Lights	COLREG	x		x	x	i		x	i	x	x	
GMDSS Operations and Testing	SOLAS/STCW	x		x	x	i		x	x	x	x	
EPIRB and SART	SOLAS	x		x	x	i		x	x	x	x	
Ship and Cargo Operations including Pollution Prevention												
Loading and Stability Manuals	IBC/BCH	x		r	r	r	x	r	r	x	x	Chief Officer, Chief Engineer
Cargo loading limitations	IBC/BCH	x		r	r	r	x	r	r	x	x	
Damage/survival stability guidelines	IBC/BCH	x		r	r	r	x	r	r	x	x	
Procedures and Arrangement Manual	MARPOL	x		r	r	r	x	r	r	x	x	
High level alarms operative	IBC	x		x	x	i	x	x	x	x	x	
Bilge Alarms	SOLAS	x		i	x	i	x	i	i	x	i	
Portable or fixed gas detection systems	SOLAS	x		x	x	i	x	x	x	x	x	
Inert gas system (for oil tankers) or other systems to blanket cargo (e.g. nitrogen)				x	x	x	x	x	x	x	x	
15 ppm Alarm	MARPOL	x		i	i	i	x	i	i	x	i	
Oil-Mist Detector	SOLAS	x		i	i	i	x	i	i	i	i	
SOPEP, SMPEP	MARPOL	x		r	r	r	x	r	r	x	x	
Cargo Record Book, Oil Record Book, Garbage RB	MARPOL	x		r	r	r	x	r	r	x	x	
Tank cleaning and washing including COW	MARPOL	x		r	r	x	x		x	x	x	
Industry Guidelines/Publications			x					x	x	x	x	
Cargo Operations in General including Pump Room	various		x	x	x			x	i	x	x	
Cargo Transfer Operations	various		x	x	x			x	i	x	x	

Note: Compiled by author				Party performing the inspection/survey/audit								
Inspection Matrix - Main Areas of Inspection	**Source of Inspection**			**Port & Flag State or Class**				**Industry**				
	International Conventions (statutory)	**Flag State**	**Add. Industry Requirements**	**Port State (more detailed insp.)**	**Flag State**	**Class Surveys**	**ISM (emphasis on the system)**	**Insurance (P&I Clubs)**	**CDI/OCIMF**	**Rightship**	**Greenaward (Shipside Part)**	**Ship Crew Involved**
Fuel Testing, sulphur content measurement			x								r	
Anti-fouling system for hull coating (TBT free)	MARPOL	x			r				r		r	
Additional Oil Pollution Prevention Measures			x						r		r	
Machinery Related Areas including Engine Room												
Engine Room Standing Orders	SOLAS/ISM	x		x	x	x	x	x	x	x	x	Chief Engineer, First or Second Engineer
Planned Maintenance System	SOLAS	x		r	r	i	x	r	i	x	x	
Emergency Steering Gear	SOLAS	x		i	i	i		i	i	i	i	
Emergency Fire Pump	SOLAS	x		i	i	i		i	i	i	i	
Emergency Generator	SOLAS	x		i	i	i		i	i	i	i	
Emergency Batteries	SOLAS	x		x	x	x		x	x	x	x	
Testing of Black Out and Reverse Polarity				i(s)		i			i(s)	i(s)	x	
Overall Cleanliness and Appearance of ER				x	x	x	x	x	x	x	x	
Stability & Structure												
Enhanced Survey Program, Thickness Measurements	SOLAS	x		r	r	i(s)	r	r	r	r	r	Master, Chief Officer, Chief Engineer
CAS (Condition Assessment Scheme)	MARPOL	x		r	r	i(s)	r	r	r	r	r	
Inspections of Ballast Tanks, Cargo Tanks, Void Spaces, Cofferdams for Condition of Coating/Corrosion	SOLAS/MARPOL			x	r	i(s)	r	r	x	i	r	
Rating System for Condition of Coating/Corrosion	as per ESP/CAS	x		r	r	i(s)	r	r	r	i	r	
Conditions of Hull and Superstructure (e.g. Hatch covers)	Good/Fair/Poor	x		x	x	i(s)	x	i(s)	x	i	i	
Class Status Report/Outstanding Class Conditions and Memoranda			x	r	r		r	r	r	r	r	

The table is split into the main areas of inspection such as an administrative part, living and working conditions onboard the ship, the safety management system, areas related to safety and fire appliances, navigation and communication, ship and cargo operations including pollution prevention, machinery related areas and stability and structural related areas. The source of inspection is listed when applicable which can be a combination of the international conventions plus flag state requirements and additional industry requirements besides the statutory requirements. Next, the parties performing the inspections are identified and their coverage is indicated. The last column provides guidance on the crew that is involved in the inspections. For some vetting inspections and class surveys, the ship superintendent will normally also be onboard the vessel to assist the crew.

The inspection normally starts with a short briefing of the master and review of the ship's certificates and crew certificates. This is followed by a deck round starting from the top (bridge) down to the main deck areas with stops at the life boats, safety lockers, fire fighting equipment. The bridge will also cover more detailed questions about passage planning, chart corrections and the checking of the navigational equipment, lights and radio equipment. Deck rounds can entail stops at the paint locker, the CO_2 room (if applicable), storage location for Acetylene and Oxygen Cylinders, the pump room (if applicable), the emergency generator, checking of fire hoses and lifebuoys, mooring arrangements and winches as well as visits to the forepeak. The last section of the inspection normally covers the cargo control room and the engine room with the testing of the emergency fire pump and emergency steering gear and a general round around the engine room including the areas used for welding. If ballast water tank inspections or inspections of the cargo holds are performed, the inspector will announce this in the beginning of the inspection so that it can be prepared accordingly. It is not easy to access ballast water tanks or cargo holds during normal cargo operations. The inspection is normally finished up with a round of the galley storage areas for food (dry store, freezers, etc.) and the crew mess and day room.

One can see from the table, that certificates are referenced by everybody and that the main areas of inspections are more or less covered by all types of inspections. Living and Working Conditions of the crew are mainly covered by the inspection rounds and the actual living space of the crew (their cabins and other facilities) is hardly inspected.

The industry inspections such as CDI/OCIMF, Rightship and Greenaward pay more attention to ship and cargo operations and spend considerably more time with crew members to interview them on operational issues. These items are primarily referenced during port and flag state inspections. Drills might be performed by some safety regimes such as the USCG or flag states but are not performed frequently by other inspectors and the inspection of the lifeboat primarily emphasizes on the overall condition of the lifeboat, its launching devices and embarkation procedures as well as the lifeboat equipment. The inspection of safety and fire appliances is also covered by all types of inspections. For some items, the inspection might go into more details and entail the actual testing of the equipment which is merely performed during class surveys while other will only refer to expiry dates of the last survey/inspection that was performed shore side (e.g. for life rafts).

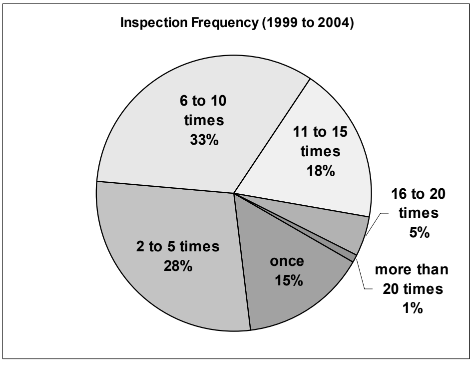
Items related to navigation and communication is also covered by all inspection types including chart corrections, passage planning, nautical publications and the overall impression of the officer on watch with reference to the handling of the equipment (radar, echo sounder, radio equipment, etc.)

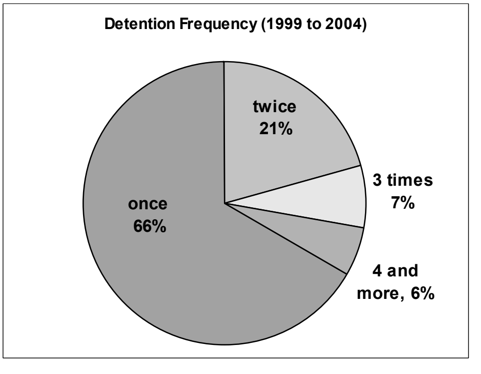
Difficult to inspect is the safety management system since it draws from all areas. All inspections do cover some ISM related questions and the actual validity of the presented paperwork only becomes evident after a general deck round and interview with crew members. It might be that the paperwork related to ISM is in compliance but not implemented onboard. Some of the findings in part III of this thesis support the idea of lack of proper implementation of ISM despite all the inspections that are performed in the name of safety. Inspection systems such as the vetting inspections do emphasize more on this aspect where Greenaward also performs company audits shore-side. Authorized classification societies or flag states perform separate audits to ensure that the safety management system is implemented in practice but inspections due to the time constraint in conducting surveys is normally only looking at the surface.

As mentioned earlier, ballast water tank and cargo holds inspections are difficult to perform and are primarily done by classification societies. Rightship pays more attention to actual physical inspections while port states will only proceed either required by their policies (e.g. expanded inspections in the EU) or when perceived necessary. The various programs (ESP, CAS or CAP) for the conditions of coatings in the ballast tanks and cargo tanks (when applicable) are normally only referenced and physical inspections thereof are kept to a minimum. The table gives a good indication of some of the overlapping of the inspections that are performed on ships from port states, flag states, vetting inspections and other industry inspections. The inspections performed by classification societies on behalf of the flag state to a certain extent have a different scope since they are the basis to extend or renew the validity of a certificate and are therefore statutory. The flag state inspections performed in addition to the surveys from classification societies primarily serve as a means to check the performance of classification societies as a recognized organization to conduct these surveys on behalf of the flag state.

The system generates a substantial amount of inspections performed on vessels with areas that are inspected and re-inspected frequently. In the case of port state control and based on the total dataset, one can see the total inspection and detention frequency in Figure 11 which is based on an average of four years[41] since not all regimes provided data for the whole time frame. Based on the 183,819 port state control inspections and 26,020 aggregated ships, this aggregates to 7 inspections within four years or approx. 1.7 inspections per year per ship.

Figure 11: Inspection and Detention Frequency of Vessels (1999 to 2004)





[41] The total amount of years for each regime was converted into month of inspections and then converted into total amount of years (291 total months/12 = 24.25 years/6 regimes = 4 years)

2.3. Summary of Costs of Inspections and Insurance Claims

Table 6 and Table 7 give an overview of the estimated costs of port state control inspections and other inspections that are performed onboard ships. The port state control inspection costs are divided into inspections with zero deficiencies and inspections with deficiencies who might take more amount of time onboard the ships. In addition, a 20% administrative charge[42] is added to the costs. The surveyor costs change from country to country and this change is not taken into consideration since data from 53 countries are in the total port state control inspection dataset. In reality, the presented figures might therefore be different but for the purpose of this study, the figures should merely give an overall indication on the costs associated with port state control.

Table 6: Total Estimated Port State Control Inspection Costs (USD)

# of Inspections		**# Hours/Insp.**		**Rate**	**Total 4 years**	**Per Year**	**Per Insp.**
zero def.	98,895	395,580	4	126	50,038,229	12,509,557	**506**
with def.	84,924	509,544	6	126	64,453,914	16,113,479	**759**
Total	**183,819**	**905,124**			**114,492,143**	**28,623,036**	**623**
			+20% Admin		**137,390,572**	**34,347,643**	**747**

Note: 1 hour surveyor = 72 British Pounds[43], 1 GBP = 0.5692 USD, Administrative Costs = +20%, compiled by author

The estimated inspection costs of a port state control inspection is USD 747 per inspection or a total of USD 34,3 million for all types of inspection. Inspections associated with zero deficiencies and without administrative costs are estimated to be at USD 12,5 million per year or USD 50 million for the total four year period. Looking at the total estimated costs per year per vessel and including shore based costs for ship owners and operators, the result can be seen in Table 7.

Table 7: Summary of Inspection Frequency, Allocated Time and Costs (USD/year)

in USD	**Estim. Frequency**	**Time (hrs)**	**Estim. Costs**	**Estim. Costs**	**Estim. Total Cost**
Inspection Type	**yearly*)**	**Allocated Onboard**	**Shore Side/Insp.**	**Ship Side/Insp.**	**Per Year**
Port State Control	2	5	747	288	2,070
Flag State Control	1	8	747	441	1,188
Class Annual Survey	1	10	10,362	517	10,879
ISM Audit	0.5	9	2,682	487	1,584
Insurance (P&I Club)	0.5	8	3,048	441	1,744
Industry Inspections: Tankers	6	10	17,663	566	29,702
Industry Inspections: Bulk	1	10	6,250	566	6,816
Industry Inspections: Other	0	0	0	0	0
Total Tankers	**11**	**50**	**35,248**	**2,739**	**47,166**
Total Dry Bulk	**6**	**50**	**23,835**	**2,739**	**24,280**
Total Other Ship Types	**5**	**40**	**17,585**	**2,173**	**17,464**

*Note: compiled by author, *) the ISM Audits and P&I Club Inspections are not performed yearly; For Industry Inspections, administrative portion of 20% are added which might be higher in reality due to substantial amount of preparation work*

[42] as per information obtained from the Maritime and Coast Guard Agency, UK
[43] as per information obtaine from the Maritime and Coast Guard Agency, UK

The data is a summary from several sources from the industry such as classification societies and ship owners of which the companies would like to remain anonymous. The table is split up into three groups. The estimated total frequency of inspection for tankers (oil and chemical tankers) is estimated to be at 11 inspections per year which can of course vary per ship type and age of the vessel. As the age increases (above 10 or 15 years), the frequency of industry inspections can increase. For dry bulk carriers, the inspection frequency is estimated to be 6 inspections and all other ship types, it is estimated to be at 5 inspections.

Shore based costs include the costs for the inspections itself including travel expenses as well as an administrative portion of preparing the inspections and to comment on the inspection reports which can take considerable amount of time on the ship operator's or owner's side. Total costs per year per vessel associated with inspections vary from approx. USD 47,000 for tankers to USD 17,500 for other ship types which are not part of the industry vetting inspection system. These costs represent total costs where the ship owner's portion would be the portion without port state control and the flag state inspections.

It is difficult to bring these costs in relation to the costs that are associated with casualties. One attempt was made to gather insurance claim data but only two sources from the industry could be obtained of P&I Clubs[44] who were willing to provide claim figures for the years 2000 to 2004 per ship type and claim category. An average claim figure per ship was calculated and is presented in Table 8.

Table 8: Average P&I Club Claim Figures per Vessel and Year (2000 to 2004)

Average Claim in USD (2000 to 2004)	Cargo/GA	Collision	Contact	Personnel	Pollution	Other	H&M	Average ST
GG & Container	9,794	36,071	18,084	14,396	46,796	16,303	151,181	41,804
Dry Bulk	14,767	58,311	9,955	11,495	51,078	73,207	182,399	57,316
Tanker	42,936	88,277	21,079	18,216	272,016	44,596	609,252	156,624
Passenger	1,885	56,142	9,209	15,310	18,616	9,015	883,549	141,961
Other	9,231	18,801	478	6,446	6,886	38,357	557,692	91,127
Average/vessel	**15,722**	**51,521**	**11,761**	**13,172**	**79,078**	**36,296**	**476,815**	**97,766**

Note: compiled by author, GA = general average[45], H&M = Hull and Machinery

In reality, the figures will be higher than presented in the table due to the fact that the claim figures are based on actual claims above the deductible. The deductible can vary per ship type, size, or ownership of the vessel. In addition, it varies considerably between hull and machinery (H&M) and other P&I club claims[46]. The figures presented in the table can therefore only be seen as a very rough idea of the magnitude of casualty claims per ship type. It is difficult to compare the costs of inspections with the insurance claim costs but an overall comparison per ship type is given in Table 9. The result indicate that

[44] The P&I Clubs wish to remain anonymous.

[45] legal principal of maritme law according to which all parties in a sea venture proportionally share any losses resulting from a voluntary sacrifice of part of the ship or fleet to save the whole in an emergency (definition from: http://en.wikipedia.org/wiki/General_average)

[46] As per industry sources, the deductible for Hull and Machinery can be between USD 50,000 to 250,000 and for P& I Clubs between USD 5,000 – 30,000 for personnel and USD 10,000 to 100,000 for all other claims.

the total inspection costs per ship of USD 24,768 seems to be reasonable in relation to the average insurance claim costs of USD 97,766 which in reality might be an even higher figure.

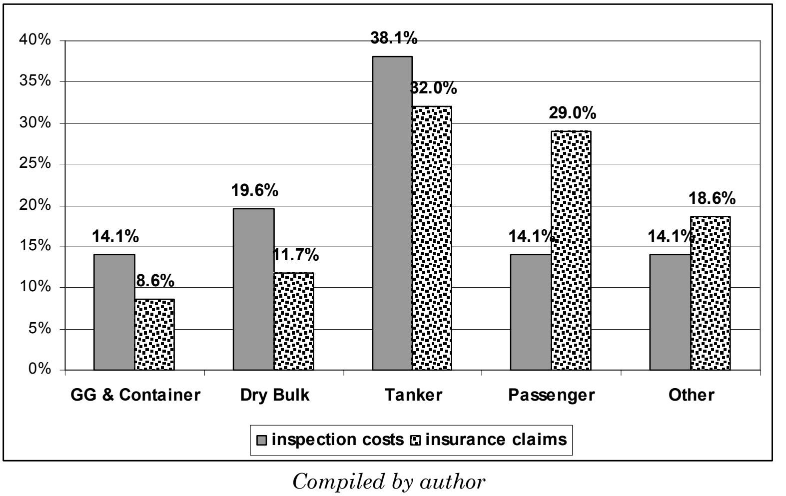
Figure 12 shows the split up of the inspection costs and insurance claims per ship type in order to see the relation between the two categories. One can easily see that the percentages are not in line for passenger vessels where the insurance claims are substantially higher than the inspection costs. For tankers on the other hand, the higher inspection costs seem to be in line with the insurance claims due to the high costs that are for instance involved if pollution is involved in a casualty.

Table 9: Average Inspection Costs versus Insurance Claims in USD (2000 to 2004)

In USD per vessel	Inspection Costs	Insurance Claims
GG & Container	17,464	41,804
Dry Bulk	24,280	57,316
Tanker	47,166	156,624
Passenger	17,464	141,961
Other	17,464	91,127
Average per Vessel/year	**24,768**	**97,766**

Compiled by author

Figure 12: Inspection Costs versus Insurance Claims in % to Total



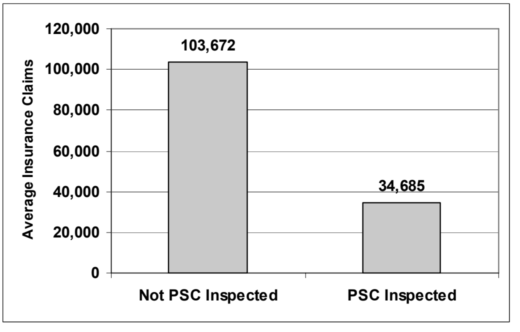
Compiled by author

It is difficult to conclude if the inspection costs are in relation to the insurance claims and if the relative high frequency of inspections on oil and chemical tankers is justified since the costs of preventing accidents due to inspection are not known. In addition, the insurance claims costs are in reality higher than shown here and only based on two P&I Clubs. For the regression analysis on casualties and the effect of port state control in the probability of having a casualty, the insurance claim costs were not taken into consideration but are based on the seriousness of a casualty instead.

To get an impression about the difference in insurance claims of vessel that were inspected with vessels that were not inspected, the following graphs should give an impression to see the difference based on claim costs. The graphs were produced the following way. The total casualty dataset was combined with the insurance claim costs listed in Table 8 and then aggregated per IMO number in order to obtain an average claim amount per ship since one ship can have more than one type of claim. The result was then merged with the inspection dataset in order to identify if a ship has been inspected or not inspected by port state control. The figures do not match the figures presented in Table 9 since they are averages across all ship types and based on the total casualty dataset and not the claim information received from the P&I Clubs directly.

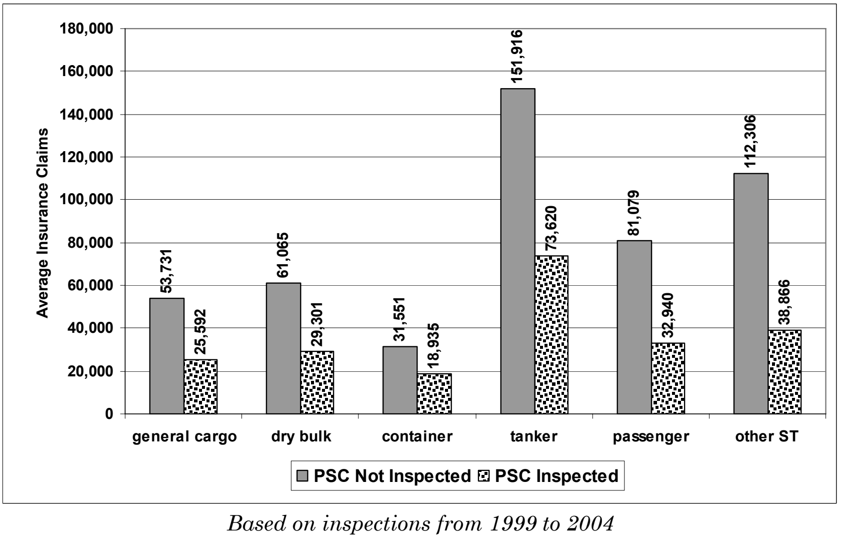
Figure 13 gives an overview of the total average claims of inspected vessels versus not inspected vessels. One can easily see that not inspected vessel have higher average claim costs than inspected vessels. The same applies for Figure 14 for the average claim costs per ship type based on the casualty dataset but using the average claims that were calculated and shown in Table 8.

Figure 13: Average Claims of Inspected versus Non-Inspected Vessels



Based on inspections from 1999 to 2004

Figure 14: Average Claims of Inspected versus Non-Inspected Vessels per Ship Type



Based on inspections from 1999 to 2004

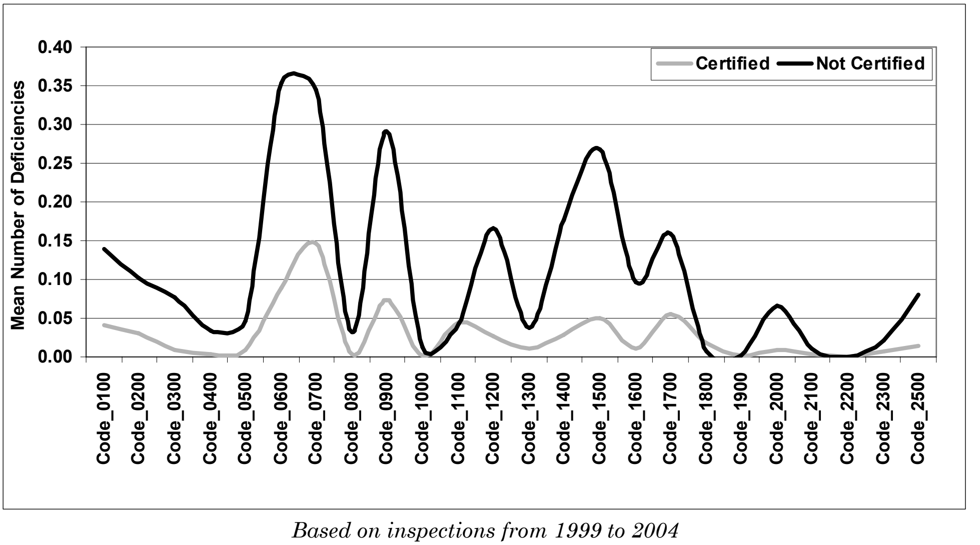
One can see that the differences between inspected and not inspected vessels is greatest for tankers and other ship types which are easily explained with the frequency of inspections performed on oil tankers. The next chapter will give a short overview of remedies that could be identified to enhance compliance and new legislative developments in the area of maritime safety.

2.4. Remedies to Enhance Compliance and New Developments

2.4.1. Industry Based Incentives

Two systems have been identified which take commercial incentives to improve safety into account. The first one is the system established by the Greenaward Foundation explained previously where the ship owner receives discounts on harbor dues from various ports around the world. Data from the Greenaward Foundation was merged with the total dataset for port state control inspections to see if there is any substantial difference between ships that have a "Greenaward" certificate versus ships that are not certified and the result can be seen in Figure 15.

Figure 15: Mean Amount of Deficiencies on Greenaward Certified Ships



Based on inspections from 1999 to 2004

On average, ships that are certified by "Greenaward" show a lower amount of deficiencies in almost all categories versus ships that are not certified. In the area dealing with safety and fire appliances (code 600 and 700), this difference is significant. The same applies for code 900 (structural safety), code 1200 (load lines), code 1500 (safety of navigation) and code 1700 (MARPOL Annex I: Oil Pollution). Overall, the mean amount of deficiencies per inspection is at 2.6 deficiencies for not certified vessels versus 0.7 for certified vessel and one can conclude that Greenaward certified vessels show a better performance in port state control than non-certified vessels and that the incentive to perform better does pay off for the ship owner. On the other hand, the certification does not necessarily mean that the ship gets inspected less within the port state control regimes. Probabilities of casualty will be shown in part III of this thesis (Figure 83).

2.4.2. Current Regulatory Based Incentives

The second system which has been identified to provide incentives for ship owners to perform better is the Qualship21 program of the US Coast Guard and the revised directive on port state control of the EU. For the USCG and depending on the vessel's inspection history, ownership, flag and classification society, Qualship21 status can be obtained. Once received and depending on the ship type, the vessel will then be exposed to less port state control inspections. For cargo ships, this period is 2 years. Passenger vessels can also participate but will not benefit from fewer inspections due to the perceived risk. The filtering process used by the US Coast Guard also contains past casualty history of the vessel while it is not clear how this data is incorporated into the overall process.

2.4.3 New Developments in the EU

New developments to review the present targeting system of the EU area through the Paris MoU derive from a new proposal of Council Directive 95/21/EC[47] as part of the Third Maritime Package. Besides the revision on port state control, the EU Third Maritime Package also contains other measures such as the development of a common accident investigation[48] and reporting scheme and the clarification of ports of refuge. A very interesting measurement with respect to flag states is the transfer of the IMO Voluntary Member States[49] Audit Scheme into EU law which will then be mandatory and enforceable under EU law. The IMO Voluntary Member States Audit has been adopted in December 2005 during the 24th Session of the IMO Assembly and will be explained in one of the subsequent chapters. This is a welcoming measure to improve enforcement and acceptance of the scheme in the maritime industry.

The main objective of revision of the port state control directive is to ensure better use of present resources to fully cover high risk vessels and to decrease the inspection burden on low risk vessels. This thesis can support this new change in course based on the findings of this thesis in part III. The main points of the proposal are summarized below[50]:

- Harmonize application of the directive with respect to the new member states and harmonized training of port state control officers.
- Revision of the process of banning ships (refusal of access) including all ship types and the proposal for permanent banning from community ports.
- The increase of transparency through the publication of black lists for substandard owners and a list of ranking for classification societies.
- Revision of the present targeting system to a risk-based system including a revision of the application of expanded inspection and the improvement of the follow up of outstanding deficiencies. The new inspection regime will also try to establish a system which should allow the division of inspections across the whole EU area.
- More attention is placed to the human factor such an increased awareness of falsified crew certificates. In addition, any complaints of crew members regarding living and working conditions onboard a vessel should be investigated and also followed up.

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47 http://europa.eu.int/comm/transport/maritime/safety/2005_package_3_en.htm

48 Proposal for a Directive establishing the fundamental principles governing the investigation of accidents in the maritime transport sector and amending Directive 1999/35/EC and 2002/59/EC, COM (2005). 590 final version of 23rd November 2005

49 IMO Resolution A.973(24) and IMO Resolution A.974(24)

50 Based on the Proposal for a Directive, COM (2005), 588 final version of 23rd November 2005

The revision contains a new approach to banning ships from the EU. First, it incorporates a time frame for period of banning of 3 months for the first banning and 12 months for the second banning and second, it allows for permanent banning for an additional detention after the second banning. It is difficult to estimate the effect of this new proposal once it has been implemented. It will certainly have an effect on one of the categories of ship types which could not be banned previously but have the highest number of detentions – the general cargo ships. Some of the shift of substandard vessels across the regions can already be measured and is shown in part III of this thesis.

On the other hand, the effect of permanent elimination of substandard ships versus a shift towards other trading areas is difficult to foresee. The act of detention is in general good for the vessel since it ensures that rectification of the deficiencies found is dealt with and that the vessel complies with the minimum standards after the release of detention. After the ship has been released from detention, the banning based on the criteria of a ship not meeting the minimum safety standards is not correct but is merely a tool to punish ship owners for not complying. It is questionable if this remedy will really raise the safety standards and what the economic impacts might be on the long run. A different approach might be to impose fines to ships that had multiple detentions instead of banning them altogether. In this way, there is more control over substandard ships that can benefit from inspections and detentions, in particular for the living and working conditions of some crew members who serve on substandard vessels.

In applying main criteria for detention including the areas that are covered under the ILO conventions, the port state control officer is only supposed to look at the forthcoming voyage. The overall safety of a vessel does not only depend on the forthcoming voyage but derives from a continuous operation of the vessel, especially of the successful implementation of the safety management system onboard. One should therefore look at the safety management system in place and its probability of continuation beyond the forthcoming voyage since the probability of the ship being inspected at the forthcoming voyages is lower in the same regime. Cooperation between the regimes would therefore be beneficial and beyond the boundaries of the ship's sailing area at the time being but within the next 2 to 3 months.

Fatigue is defined by the IMO as follows[51]: "*A reduction in physical and/or mental capability as the result of physical, mental or emotional exertion which may impair nearly all physical abilities including: strength, speed, reaction time, coordination, decision making or balance.*" In the maritime environment, it is difficult to keep a concise schedule with respect to resting periods. Besides the quantity of sleep, the quality of sleep is also important and if one is deprived from sleep for a long period, the sleep deficit accumulates. It is difficult for a port state control officer or any other inspector to correctly observe and identify deprivation of sleep and or the signs of fatigue at the time of the inspection when crew members normally try to accommodate the inspector as good as possible. It mostly happens that some of the resting periods are also violated due to an inspection.

Another area of new EU legislation deals with the liability of classification societies and suggests the introduction of financial sanctions for failures to comply. While these suggestions are still part of the Third Maritime Package, two additional measures deal with the harmonization of criminal law enforcement against ship-source pollution

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[51] Goodwin,S (2006), Does Work Keep you Awake at night?, *Learning from Marine Incidents III, Conference*, The Royal Intitute of Naval Architects (January 2006: London, UK)

(Council Framework Decision) and penalties for infringements (Directive)[52]. Both measures have been adopted and should be implemented in January 2007 and March 2007 respectively. The council framework decision does not fall under the EU court of Justice jurisdiction[53] while the directive does. Both measures complement each other and provide a framework to address infringements including criminal offences and extend penalties not only to ship-owners or master of a vessel but also to cargo owners and classification societies.

A third measure dealing with the civil liability and financial securities of ship-owners in the form of a directive has been proposed by the Commission in November 2005 and is under review by the Council and European Parliament. The directive's objective is to increase the civil liability of ship owners and to make insurance coverage obligatory which in the view of the EU is not covered by the international regime. If further introduces protection for seafarers in case of abandonment. The respective international conventions are as follows:

1. International Convention on Civil Liability for Oil Pollution Damage, 1992(CCL) & 1996 Protocol
2. International Convention of 1996 on Liability and Compensation for Damage in Connection with the Carriage of Hazardous and Noxious Substances by Sea (HNS) – not in force yet
3. International Convention on Civil Liability for Bunker Oil Pollution Damage, 2001 (Bunker Oil Convention)

2.4.4. The New ILO Consolidated Maritime Labor Convention (2006)

In February 2006, the ILO adopted the new Consolidated Maritime Labor Conventions which updates and consolidates 68[54] existing ILO maritime conventions and recommendations. The adoption and revision of this new convention is expected to improve the living and working conditions of the seafarers as well as clearly state their rights. It consists of five titles as follows[55]:

Title 1: Minimum requirements for seafarers to work on a ship
Title 2: Conditions of employment
Title 3: Accommodation, recreational facilities, food and catering
Title 4: Health protection, medical care, welfare and social security protection
Title 5: Compliance and enforcement

One of the main purposes of the new conventions is also to enhance implementation of common standards across the industry which is treated in Title 5. In order to do so, it provides for a complaint procedure for seafarers and a certification system of labor standards by the flag states.

The certification consists of two parts – the *maritime labor certificate* and a *declaration of maritime labor compliance*. The maritime labor certificate is issued by the flag state upon

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[52] Council Framework Decision 2005/667/JHA of 12th July 2005 and Directive 2005/35/EC of 7th September 2005

[53] since it was adopted under Title VI of the Treaty of the European Union and therefore falls under the third pillar of the EU. Framework decisions are binding for the members states but the choice of method on how to implement the decision is left to the member state.

[54] ILO: http://www.ilo.org/public/english/bureau/inf/event/maritime/index.htm

[55] ILO: http://www.ilo.org/public/english/dialogue/sector/papers/maritime/consolcd/conv.htm

an inspection where the inspection can be delegated to authorize classification societies and is valid for five years where periodic inspections are required. The declaration is a document of the flag state which summarizes the national laws and regulations as well as a plan of the ship owner or manager on how to implement these and how continuous improvement can be achieved. The areas that are covered under the declaration are as follows[56]:

1. Minimum Age
2. Medical Certification
3. Qualification of Seafarers
4. Seafarer employment agreements
5. Use of a licensed or certified or regulated private recruitment and placement service
6. Hours of work or resting hours
7. Manning levels for the ship
8. Accommodation
9. On-board recreational facilities
10. Food and catering
11. Health and safety and accident prevention
12. Onboard medical care
13. Onboard complaint procedures
14. Payment of wages

A continuous record of deficiencies that were found during inspections is to be kept onboard as well as applicable remedies. The system is similar to the safety management system. These records are then made available to inspectors for flag states and port states.

Port State control will inspect the certificates in an initial inspection and if clear grounds indicate the need for a more detailed inspection, the port state control officer will do so and can detain a vessel is clear evidence of non compliance to the provisions in the declaration of the maritime compliance is found. In addition, complaints from seafarers or professional bodies that have an interest in the safety of the seafarers are to be treated with confidentiality and can constitute grounds for a more detailed inspection. In this respect, it is worth noticing that IMO has developed PSC guidelines on seafarer's working hours during FSI[57] 14 (June 2006).

The new convention is a very welcoming development in trying to increase the acceptance of the ILO standards and enforce them. The inspections will probably be performed primarily by the recognized organizations – the classification societies and will be added to the other inspections or surveys that are performed onboard the ships. It will be interesting to see how the complain procedure for seafarers will work in practice and how inspectors will inspect the areas. It is a first step towards improvement of living conditions. Hopefully, more attention will be given to the living and working conditions of some seafarers during inspections so that improvements can be made.

[56] ILO: http://www.ilo.org/public/english/dialogue/sector/papers/maritime/consolcd/conv.htm

[57] Flag State Implementation Sub-Committee Meeting (June 2006). The correspondent Working Paper is FSI 14/WP.3, 8th June 2006

2.4.5. The Voluntary IMO Member Audit Scheme

The IMO has adopted two important instruments in December 2005 which are Resolution A.973 (24) namely the Code for the Implementation of Mandatory IMO Instruments and Resolution A. 972(24) which provides the Framework and Procedures for the Voluntary IMO Member State Audit Scheme. It comprises flag states, port states and coastal states and aims in improving the interpretation and implementation of the IMO instruments by the parties involved. The mandatory instruments in the code are as follows:

1. SOLAS and Protocols of 1978 and 1988
2. MARPOL and Protocol of 1997
3. STCW
4. Load Lines and Protocol 1988
5. Tonnage Convention
6. Convention on the International Regulations for Preventing Collisions at Sea

The code clearly defines the responsibilities of flag states, port states and coastal states in implementing the conventions mentioned earlier. It further builds on the United Nations Convention on the Law of the Sea (UNCLOS, 1982) in which administrations are responsible to ensure that a ship and its crew is fit to operate a vessel. The code allows authority to conduct surveys to be delegated to recognized organizations (the classification societies) of which the guidelines are found in Resolution A.739 (18)[58]. Areas which are covered in the code are the responsibilities of a maritime administration with respect to the administration of the registry and enforcement either on the flag or port state level, accident investigations and the qualifications of surveyors.

The framework lists detailed audit procedures to audit the flag and port states and coastal states. As of now, it is a voluntary scheme but the first of its kind for IMO to allow the organization to perform audits. The scheme is seen as a tool to help the administrations to implement the conventions into national law and to improve their interpretation. The areas which are covered during the audit are as follows:[59]

1. *Organization and authority*
2. *Implementation of IMO conventions into national law*
3. *Jurisdiction and Enforcement arrangements*
4. *Approval of Authorized organization*
5. *Appointment of surveyors*
6. *Accident investigations and Reporting to the IMO*

The audit process is shown in Figure 16 below with detailed steps. It is split into a planning process, an executing process and a reporting and follow-up process. The member state requesting the audit agrees to make some of the findings available for other member state which should enable to increase transparency and provide assistance to flag states that are willing to learn lessons from the audit of other administrations.

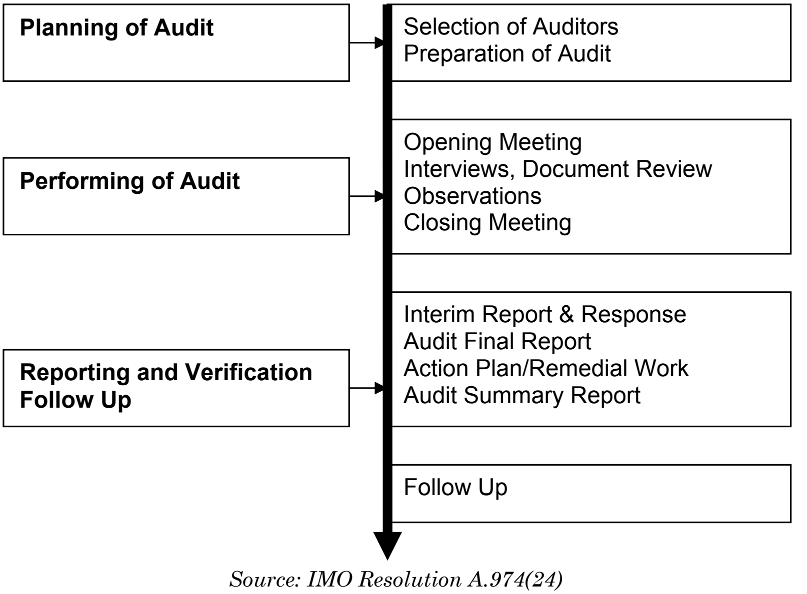
The auditors are appointed by IMO. After the planning stage, the audit is performed and an interim report is issued to the member state and at this stage is only made available to the audited member state. The member state then has the opportunity to make comment on any disagreements in the interim report by writing. The final audit report is then

[58] IMO Resolution A.739 (18) adopted on 4th November 1993: Guidelines for the Authorization of Organizations acting on behalf of the Administration

[59] IMO Resolution A.974(24): Framework and Procedures for the voluntary IMO Member State Audit Scheme

issued to the member state and in consolidated version in a form of an audit summary report will be made available to the IMO secretariat. The member state is also requested to address any of the audit findings.

Figure 16: Auditing Process



Source: IMO Resolution A.974(24)

The idea of conducting voluntary audits is a very welcoming development within the IMO framework and if transferred into EU law in the case of the EU will certainly help in improving the implementation and interpretation of IMO conventions. Although a voluntary tool, it might become more or less mandatory for some large flag states and allows for giving an incentive through decreased port state control inspections.

2.4.6. Newest Developments in the Area of PSC at IMO

FSI[60] 14 held in June 2006 enjoyed many submissions for agenda item 6 – Harmonization on Port State Control. During the session, it was acknowledged that a framework on global harmonization and co-operation on PSC activities should be established. The working group recognized that the following should be reached globally[61]:

- *harmonized (compatible) procedures of PSC inspections,*
- *harmonized (unified) actions against vessels having deficiencies; and*
- *availability of PSC inspection results to all officers conducting PSC inspections worldwide.*

The group further identified specific tasks that needed to be implemented in order to harmonize port state control activities which are listed here below in condensed format:[62]

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[60] Flag State Implementation Sub-Committee Meeting, IMO, June 2006

[61] FSI 14/WP.3, Report of the Working Group on Harmonization of Port State Control Activities, page 5

[62] FSI 14/WP.3, Report of the Working Group on Harmonization of Port State Control Activities, page 6

- *Ratification of relevant IMO instruments*
- *Unified interpretation of relevant legal instruments and code of conducts*
- *Compatibility of PSC procedures including reporting, coding, statistics, notifications and right of appeal*
- *Transparency of information and co-operation and information exchange between member states and MoU's including PSC data*
- *Analysis of PSC activities, practices and statistics*
- *Training including revision of IMO training material*

These latest developments are a major step into the direction of increasing the effectiveness of port state control. This concludes the qualitative analysis of the present safety regime including some of the newer developments in the areas concerning maritime safety.

2.5. Summary of the Safety Regimes and Inspection Regimes

This chapter provided an overview of the overall complexity of the safety regimes. Many players are part of the safety systems consisting of a mandatory (statutory) part and a non mandatory part (industry driven). The mandatory part based on the legal framework and normally enforced by the flag states is nowadays more and more performed by recognized or authorized organizations (the classification societies) and as a last resource by the port states. New developments in the area of labor related inspections are also expected to fall within the area of classification societies.

Comparison of the port state control legal bases showed that there are differences in their target factors to target vessels which might also reflect regional requirements. Port state control is influenced by the world trade flows and their respective ship types that will visit a particular regime. Differences in operational standards might be due to the different experiences that the regimes have due to their number of years in existence and the different backgrounds their inspectors have. However, all regimes do refer to the applicable IMO guidelines for port state control inspections and identify "clear grounds" and "non favorable treatment" for ships flying a flag which is not party to the conventions in question. The USCG, AMSA, and the Paris MoU (through the EU) have stronger enforcement possibilities and remedies for non-compliance than for instance the Indian Ocean MoU or the Viña del Mar Agreement. Each of the segments of the maritime industry (dry bulk, liquid bulk, containers etc.) have distinctive commercial and operating surroundings which also influence the level of safety of each of these ship types and the experience of the inspectors of the regimes.

The lack of trust in the industry between flag states, port states, classification societies, insurance companies, and cargo owners has created a playground for many inspections which are performed on certain ship types (oil tankers, chemical tankers and dry bulk carriers) nowadays in the name of safety. The areas that are inspected in all of these inspections show a considerable amount of overlapping between statutory and industry driven inspections. In addition, the safety regimes do not accept port state control inspections that are performed in another regime. This leaves certain ship types to be exposed to a relatively large amount of inspections where the inspections are performed sometimes during critical port operations and take time away from the crew. With shortened time in ports, the inspections can increase the working hours of shipboard personnel considerable. None of the inspections takes this into account or actually looks closer into working and living conditions of the crew in particular the working and resting hours. The new ILO convention is a welcoming development and will hopefully increase compliance with the minimum working and living conditions onboard ships.

The lack of enforcement of the minimum international standards also shows the political sensitivity of this topic overall and further underlines the lack of trust and cooperation between the players and the various port state control regimes. The underlying question is how the functioning of the safety regimes can be improved and how the money which is allocated to port state control can be better used to eliminate substandard ships?

The estimated inspection costs of a port state control inspection is USD 747 per inspection or a total of USD 34,3 million for all types of inspection. Inspections associated with zero deficiencies and without administrative costs are estimated to be at USD 12,5 million per year or USD 50 million for the total four year period. Total inspection costs per vessel per year are estimated to vary from USD 47,000 for tankers to USD 17,500 for other ship types while the frequency of inspections can also vary considerably but is estimated to be at 11 inspections per year for tankers, 6 for dry bulk carriers and 5 for all other ship types. Comparing average insurance claim costs of vessels that have been inspected with vessels that have not been inspected, one can clearly see that the average insurance claim costs are higher for non inspected vessels and the difference between the two categories is further highest for tankers.

One could argue that the inspections that are performed on ships with zero deficiencies which is about 54% of the total inspection dataset and its associated costs (USD 12,5 million per year) could be used for training and to further created the necessary framework to harmonize port state control activities by assisting emerging regimes where more substandard ships are to be found. During the last FSI (14) in June 2006, harmonization of port state control was considered and a working group established which should create the necessary framework in order to achieve harmonization. This aspect will further be analyzed in part III of this thesis.

The new IMO Voluntary Audit Scheme for flag states, port states and coastal states is the first measure to address the interpretation and enforcement problem directly. It is a tool which can be supported in many ways such as incorporating it into target factors for port state control or any other inspections.

This chapter provided an overview of the individual players of the safety regime and how the players interact which is important to understand in the chapter to follow in this thesis. It further shows the overall complexity and legal framework of port state control and any other inspections that are performed in the name of safety onboard vessels. The link to the next chapter is the understanding of the industry and how it operates in order to construct the variables which will be used in the chapters to follow.

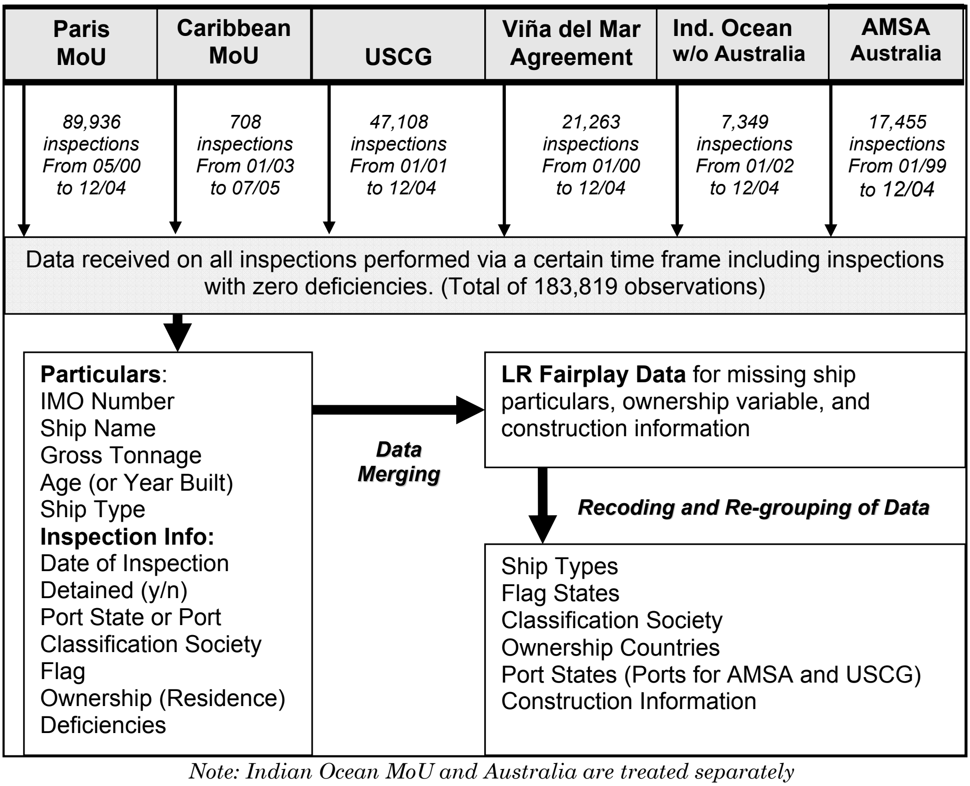
Chapter 3: Datasets and Variable Preparation

This chapter explains the database preparations and transformation for port state control data and casualty data. It further gives an explanation of the variables that are used and how the variables are grouped together as well as provide a list of definitions used in the casualty analysis. The chapter ends with a detailed analysis on the selection of ship types.

3.1. Port State Control Dataset and Casualty Datasets

All existing memoranda of understanding who are in control of an inspection database were asked to provide raw data for the analysis but not all regimes decided to cooperate with this study despite the fact that the data is most of the time publicly available on their home pages. Data from five regimes was received for the analysis and are shown in Figure 17 where the data from one regime, the Indian Ocean MoU was received in two different datasets and kept separate. The combined dataset therefore combines six data sources.

Figure 17: Port State Control Dataset Preparation



Note: Indian Ocean MoU and Australia are treated separately

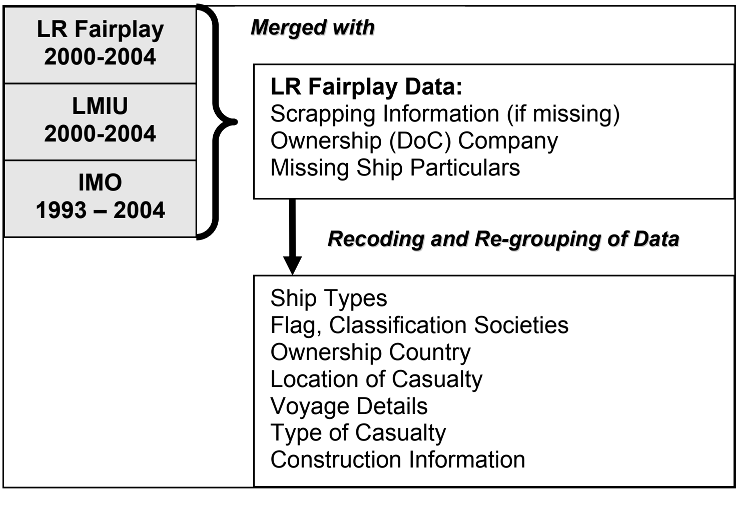
Since the Australian inspections accounted for a large part of the Indian Ocean MoU dataset (54%) and around 60% of this dataset are inspections performed on bulk carriers, the Indian Ocean MoU dataset was split between two datasets to decrease the bias of the dataset versus the Australian data. The data received contains all inspection data within a certain time frame (from January 1999 to December 2004). The US Coast Guard Marine Safety Management System (MSMS)[63] was changed in 2001 and data from the old system could not be used for the analysis and therefore starts with January 2001. The Caribbean MoU did not have any data available prior to 2003 and to increase the amount of records, data from 2005 was added to the analysis.

Unfortunately, data from the Tokyo MoU could not be obtained and therefore a certain percentage of vessels which are only inspected in this particular region are not covered by the PSC dataset of this thesis. This might affect the results of part III of this thesis which measures the effects of inspections on the probability of casualty and will be addressed in Chapter 6 and 7 respectively.

The port state control data received was merged with data from *LR Fairplay* to add any missing variables for ship particulars (age and size) and for the country of ownership of the vessel. For the country of ownership of the vessel, a special data merge was performed to add the variable indicating the Document of Compliance Company (DoC) Company. In addition, information about the construction details was added to the inspection dataset.

For the casualty datasets and corresponding variables that were used for the casualty analysis and the merge between port state control data and casualties, three data sources were used and aggregated into one dataset. Figure 18 shows the process on how this dataset was aggregated.

Figure 18: Casualty Dataset Preparation



Aggregation started with a match of data from LR Fairplay and LMIU to combine both datasets. The two datasets combined account for 9,213 records for the time period 2000 to 2004. This dataset was then merged against data from the IMO to add casualties prior to 2000 and any other casualties not included in the combined LR/LMIU dataset. The

[63] US Coast Guard Marine Safety Management System (MSMS) combines MSIS (Marine Safety Information System) which was replaced in 2001 by MISLE (Marine Information for Safety & Law Enforcement System)

additional casualty data without the corresponding port state control data (prior to 1st Jan 2000) should help with the overall casualty analysis of the data. The total dataset accounts for around 11,701 casualties. The combined casualty dataset was then merged with data from LR Fairplay to add information about the scrapping of the data (if not provided by the casualty dataset already), any other missing ship particulars and the ownership of a vessel (DoC Company). The next section will explain the variable transformation and grouping in detail.

3.2. Variable Transformations and Definitions

3.2.1. Basic Port State and Casualty Variables

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) – as per Paris MoU since the overall inspection dataset comprises of 49% data from the Paris MoU region
2) Classification Societies – IACS and Not IACS recognized
3) Ownership of a vessel as per Alderton & Winchester[64] or technical management as per LR Fairplay (DoC Company)
4) Ship Types

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 regrouped into other groups for the descriptive statistics. Table 10 below gives a list of all variable groups that are used in both types of regressions.

Table 10: Summary of Variable Groups

Variable Group	Total Number in Group	Data Type
Dependent 1: Detention	1	Binary
Dependent 2: Casualty (very serious, serious, less serious)	1	Nominal
Ship Particulars (e.g. age, tonnage, double hull, changes in flag, class, ownership, vetting inspections)	15	Nominal
Ship Types	7	Nominal
PSC Regimes	6	Nominal
Detention Indicators	6	Sums
Deficiencies (main codes) & multiplicative dummies with ST	29 (156)	Sums
Classification Societies	42	Nominal
Flag States	130	Nominal
Ownership Countries	6	Nominal
Port States/Ports	130	Binary
Ship Yard Country	37	Binary
Other Variables	3	n/a
Total for casualty models (multiplicative dummies)	**413 (540)**	
Total for detention models (multiplicative dummies)*)	**1575**	

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

A detailed list of variables with the respective coding[65] for the detention and casualty regressions is given in Appendix 4: Variable List and Respective Coding for Regressions for further detail. The actual number of the variables that is then used in the respective regressions depends on the actual dataset or portion of dataset and can therefore vary accordingly. For the detention models, all variables have been multiplied by ship type and regimes where the vessel was inspected.

Flag States

Flag States were coded individually or grouped into four major groups according to the Paris MoU Black, Grey and White List[66] 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:[67]

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[68] 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)[69] to reflect the safety culture of a certain owner and operator shore side which is also expected to be reflected onboard. The grouping of the countries into six main groups is found in Appendix 5: Grouping of Countries of Ownership for further reference but is as follows:

- traditional maritime nations,
- emerging maritime nations,
- new open registries,

[65] similar coding was used for the casualty and detention regressions for importing the data into Eviews, the software that was used to perform the regressions

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

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

[68] 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.

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

- old open registries,
- international open registries,
- "unknown" for unknown or missing entries.

The ISM Code provides a definition for the term *"Company"* which is denoted *DoC Company (Document of Compliance Company)* as follows[70]: *"Company means the owner of the ship or any other organization or person such as the manager, or the bareboat charterer, who has assumed the responsibility for operation of the ship from the owner of the ship and who on assuming such responsibility has agreed to take over all the duties and responsibilities imposed by the International Safety Management Code".*

3.2.2. List of Definitions Used in Casualty Analysis

For the sake of this thesis, it is important to define the various terms that are used in conjunction with casualty analysis such as incidents, accidents, casualties, near misses etc. The understanding of these terms and their use is important and is therefore explained here below.

Incident, Accident and Casualty[71]

In insurance terms, events that are not deliberately caused by the insured and that are not inevitable are an incident. The difference between the two is that an accident is associated with an injury and a casualty normally entails a fatality.

Near Miss/Near Accident

A near miss or near accidents are incident that could have lead to an accident or casualty but did not. It is therefore still important to analyze such events in order to understand what went wrong and how it can be prevented in the future.

Total Loss and Constructive Total Loss[72]

A total loss of the vessel is when the vessel is lost either by it being completely destroyed or submerged. A constructive total loss is equal to a total loss but in this case, it is declared a constructive total loss if the repair of the vessel would be more expensive than the remaining value of the vessel. These are cases of vessels which have experienced a substantial amount of damage and are not worth repairing.

For the sake of the thesis, the term "casualty" is used to cover incidents, accidents and casualties. In addition, the seriousness of the casualties is divided as per the IMO definition based on the MSC Circular 953 of 14th December 2000 which is as follows:

IMO: MSC Circular 953, 14 December 2000[73]

1. *Very serious casualties:* casualties to ships which involve total loss of the ship, loss of life or severe pollution, the definition of which, as agreed by the Marine Environment Protection Committee at its thirty-sevenths session (MEPC 37/22. paragraph 5.8), is as follows:

   "severe pollution" is a case of pollution which, as evaluated by the coastal State(s) affected or the flag State, as appropriate, produces a major

[70] SOLAS, Chapter IX, Regulation 1, page 425
[71] Legal terms: http://en.wikipedia.org/wiki/List_of_legal_terms
[72] Lloyd's Maritime Intelligence Unit, definitions received with the casualty data
[73] Reports on Marine Casualties and Incidents, Revised harmonized reporting procedures, MSC/Circ. 953, MEPC/Circ.372, 14 December 2000

deleterious effect upon the environment, or which would have produced such an effect without preventive action.

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
   - 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".

3.2.3. The Selection of PSC Relevant Casualties

The preparation of the casualty dataset is very important for the validity of the analysis and considerable care has therefore been placed on it. The cases were also re-classified with respect to the seriousness of a casualty as defined previously and their casualty first event as good as it could be identified by the fragmented data on hand. By combining three different sources, the most comprehensive dataset of casualties and data available for the purpose of this analysis was created.

From the total casualty dataset of 11,701 cases or 9,598 ships for the time period 1993 to 2004, more than half have been eliminated due to the incorrect time frame (1999-2004) or for other reasons which will be explained in the beginning of Chapter 5. The remaining cases are then matched against the time frame of PSC data (1999-2004) and aggregate to 6005 ships which provide the bases for the regressions in Chapter 6 and 7. Some of the descriptive statistics of the casualties are based on the total casualty dataset depending on the type and theme of the graph but is always indicated below the graphs. The next section will give an overview of the selection of ship types since the selection of ship types for port state control and casualties is equally important.

3.3. The Selection of Ship Types

As explained in Chapter 2, 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 and casualty. Taking the decision points listed under section 2.1.6. The Importance of Ship Types and Trade Flows into account, the following ship types have been re-grouped 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).

The trade flows with respect to ship types is shown in Chapter 2 while the results of the Correspondence analysis is shown in this section to underline the decision of the grouping of the ship types.

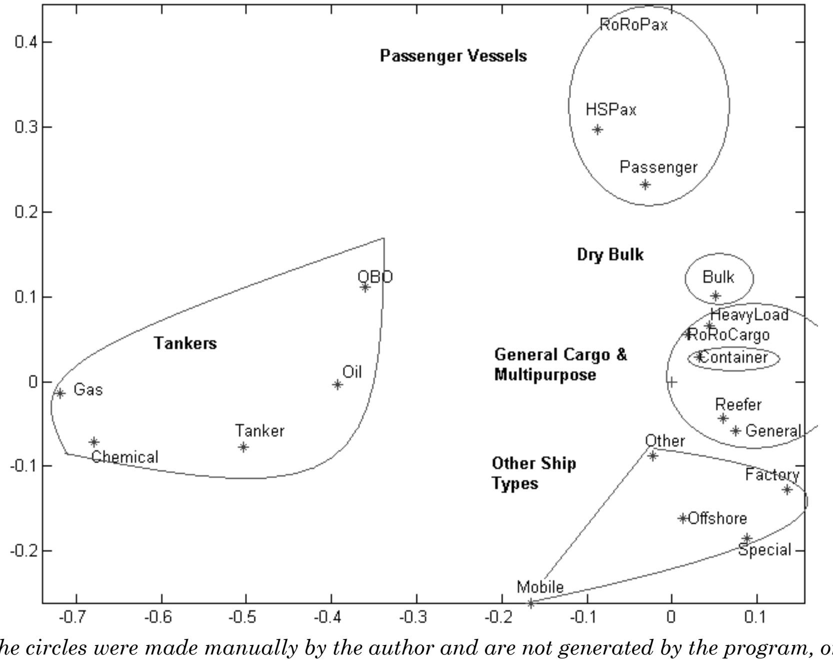
Quantitative Analysis for the Selection of Ship Types

Correspondence analysis can deal with large contingency (frequency) tables and plot distances in a two-dimensional space where the distance between the variables in question represents the association between them. Based on the contingency table, the *relative frequencies* (or conditional proportions) and the *marginal proportions* (critical masses) are calculated for the rows and columns and in this way, the row profiles can be created. Each row profile can be represented as a point in space. The average profile is the weighted average and is also the point of origin. The further a point is away from this point of origin (also called *centroid*), the more different it is from the average profile[74].

The main reason for this analysis is to further support the groupings that were performed on the ship types. The variables which were used in the plot are based on all the inspection data (approx. 183,000 inspections) and all the plots have been produced using a program written by Michel van de Velden[75]. The variables are as follows and the result can be seen in Figure 19:

1. Columns: Number of deficiencies (codes C0100 to C2500)
2. Rows: Ship Types

Figure 19: Ship Types and Deficiencies



Note: The circles were made manually by the author and are not generated by the program, only the profiles for the ship types with respect to the deficiencies are shown here

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[74] For more detailed information on Corrspondence Analysis, refer to Clausen, S.E. (1998). *Applied Correspondence Analysis* - An Introduction (Sage University Papser Series, Nr. 07-121)

[75] Michel van de Velden, Econometric Institute, Rotterdam, 2004

The numerical results can be seen in Appendix 6 for further reference. Total inertia explained is 74% in the first two dimensions. The plot shows that certain ship types group together based on their violation against the deficiency codes. Container ships are kept separate due to the commercial setup of the market segment. OBO's are between oil tankers and dry bulk carriers. Since they are closer to the tanker group, they have been aggregated with this group. Gas carriers are difficult to allocate and since there are not enough observations to create a separate group for gas carriers, the best possible group which is also underlined by the plot is to add them with the tankers.

It can therefore be concluded that the division of ship types has been conducted in the best possible way. This section concludes Chapter 3 of the thesis which gave an overview of the datasets and the variables including the ship types that are used for the remaining chapters of the thesis. It provides the foundation for the next chapter which will use the variables explained here for the regressions to follow.

PART II

This part of the thesis is the first quantitative part and looks at the differences of port state control across regimes. It tries to find the answer to the following research question:

1. What is the probability of detention across regimes and is there room for improvement?

It produces the probability of detention across regimes to see if there is room for harmonization. The probability of detention is also used in part III of the thesis where port state control data is linked to the casualty data.

Chapter 4: The Global View on Port State Control

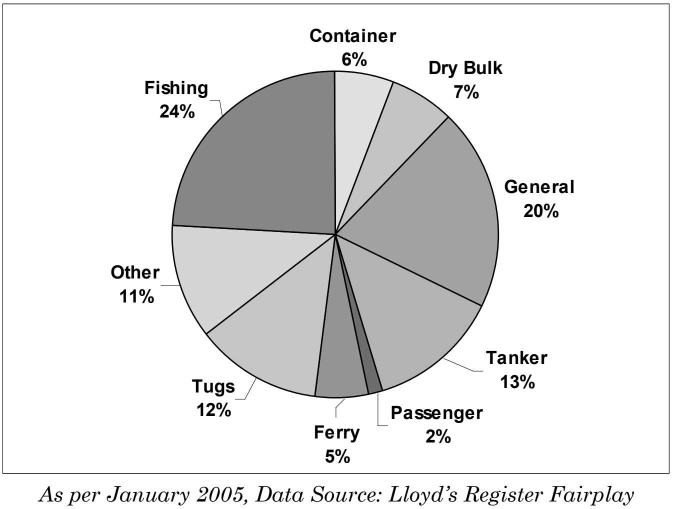
The first part of this chapter will provide some key descriptive statistics based on the port state control data followed by regression analysis which produces the probability of detention. The methods used in this chapter will take into account the different data sources of the port state control datasets.

4.1. Key Descriptive Statistics for PSC

4.1. Key Figures on Registered Vessels

The first set of graphs give an overview of the world fleet based on number of vessels registered and vessel size. Figure 20 shows the composition of the world fleet by number of vessels and Figure 22 gives an insight into the size composition of the fleet by gross tonnage.

Figure 20: Composition of World Fleet (by number of vessels)

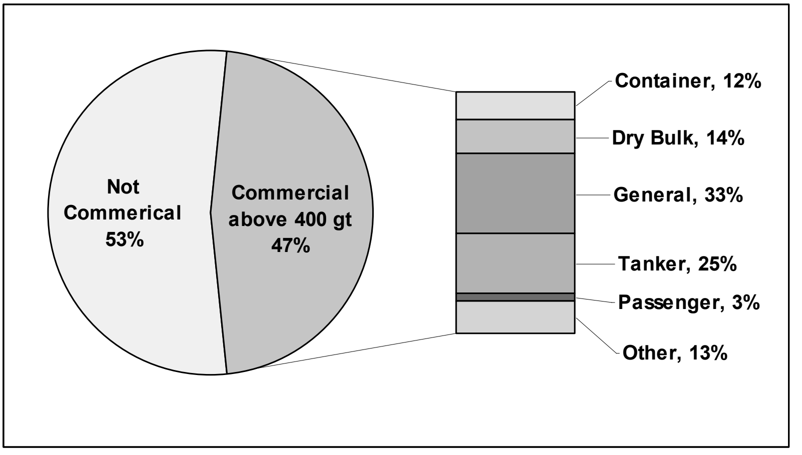


As per January 2005, Data Source: Lloyd's Register Fairplay

By comparing the two graphs, one can easily see that most fishing vessels (74%) and tugs (79%) are below 400 gt while ferries also show a high amount of vessels below 400 gt (54%). Those ships fall out of the port state control eligibility since they do not have to comply with SOLAS and MARPOL and fall under a different legal framework. The commercial fleet is composed of container vessels, dry bulk, general cargo, tankers and passenger vessels and a portion of the other ship types where smaller vessels can only be found with general cargo ships (22% below 400 gt).

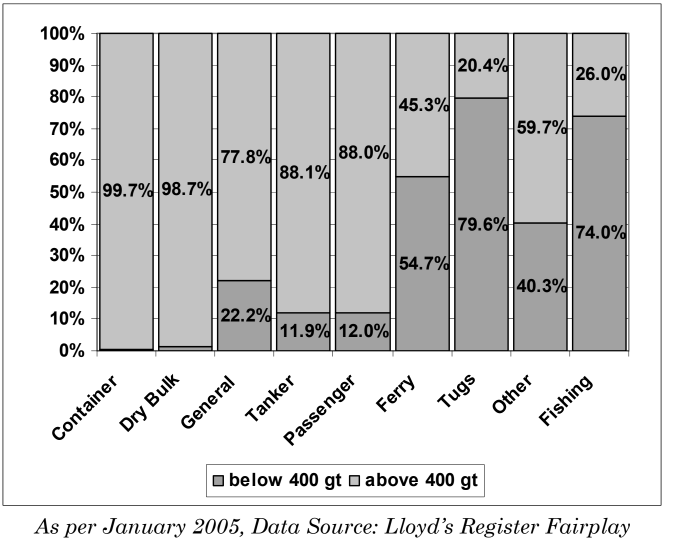
The actual split up of the commercial fleet which is eligible for inspection versus the total registered vessels can be seen in Figure 21. Most of these vessels are above 400 gt as seen in Figure 22. Oil tankers do have to comply with Annex I of the MARPOL convention if the vessels are above 150 gt otherwise the cut of is 400 gt. Most ships in service by number are general cargo ships (33%) followed by tankers (25%), dry bulk (14%) and containers (12%).

Figure 21: Ships Eligible for Inspection



As per January 2005, Data Source: Lloyd's Register Fairplay

Figure 22: Split up of Ship Sizes (gt) - World Fleet



As per January 2005, Data Source: Lloyd's Register Fairplay

4.2. Key Figures on Combined PSC Inspections

Table 11 provides a summary of each of the datasets from the various regimes and Figure 23 and Figure 24 provides the visualization of the key figures of the total dataset. The data is based on all inspections which were conducted during the time frames including information on inspections with zero deficiencies.

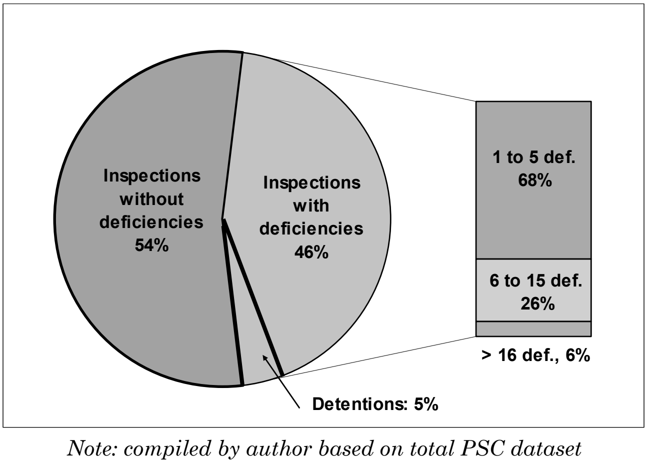
Table 11: Inspection Data Summary per MoU

Descriptive Statistics	Total Dataset	Paris MoU	Caribbean MoU	Viña del Mar Agreement	Indian Ocean MoU	US Coast Guard	AMSA
From To		05/00 12/04	01/03 07/05	01/00 12/04	01/02 12/04	01/01 12/04	01/99 12/04
Total Inspections	**183,819**	89,936	708	21,263	7,349	47,108	17,455
Detentions	**10,008**	7,005	36	644	732	660	931
Detention Rate	**5.44%**	7.79%	5.08%	3.03%	9.96%	1.40%	5.33%
Total Deficiencies	**471,764**	312,305	760	46,977	19,085	42,452	50,185
Mean # of Def.	**2.6**	3.5	1.1	2.2	2.6	0.9	2.9
Mean Age - yrs	**17**	17	18	15	18	13	11
Mean Size - gt	**22,079**	15,327	11,112	22,105	18,215	28,948	36,767
Insp. with zero def	**98,953**	39,333	597	13,359	3,943	34,560	7,161
% of insp. zero def	**53.8%**	43.7%	84.3%	62.8%	53.7%	73.4%	41.0%

Note: compiled by author based on total PSC dataset

Out of the total 183,819 inspections, 53.8% are without deficiencies and 5.4% ended in a detention of the vessel while aggregated by ship, the 53.8% decreases to 16.3% and detention increases from 5.44% to 24.6% of all inspected vessels. From the total amount of inspections of ships with deficiencies, 68% had 1 to 5 deficiencies while around 6% showed more than 16 deficiencies. One can see that the key figures presented in Table 11 vary accordingly such as the detention rate, the mean number of deficiencies per inspection and the amount of inspections with zero deficiencies.

Figure 23: Key Figures - Total PSC Dataset

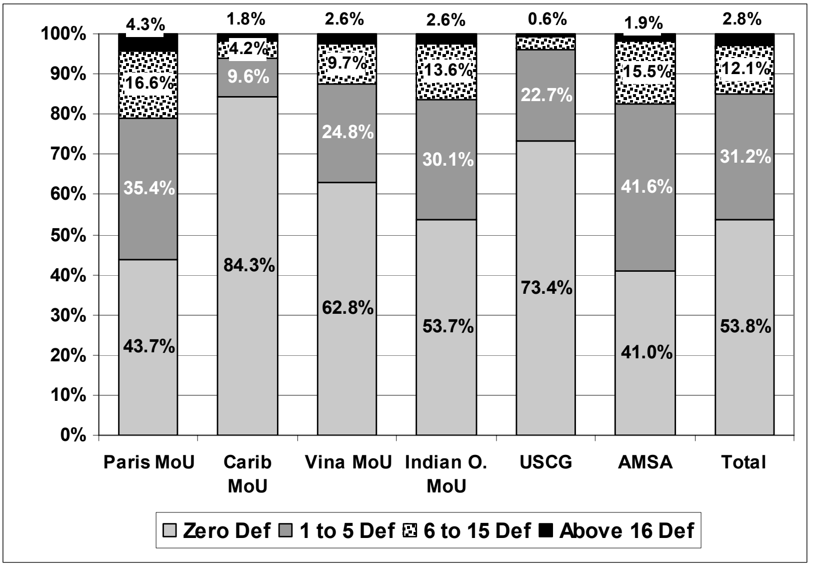


Note: compiled by author based on total PSC dataset

This does not necessarily mean that one regime performs worse than the other. Each of these datasets is the product of different legal bases and target factors described previously and the trade flows which influences the ship types. The regression analysis performed in the next chapter will highlight the differences and look into areas of possible harmonization across the regimes. A detailed split up of the amount of deficiencies per

MoU based on the total inspections of each dataset and of the total dataset is shown in Figure 24.

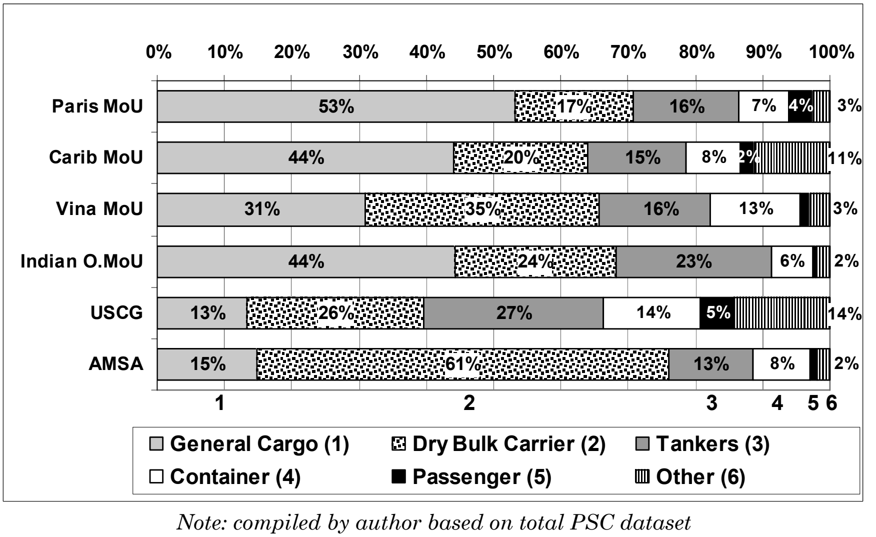
Figure 24: Amount of Deficiencies per Inspection per MoU



Note: compiled by author based on total PSC dataset

The inspection frequency of the total dataset per ship for the total time frame where the average amount of inspection frequency lies at around 7 inspections within 4 years or 1.7 inspections per year while the detention frequency of the total dataset lies at around 1.5 detentions per vessel for the same time period as shown previously in Chapter 2 of this thesis.

Figure 25: Ship Types Inspected per MoU

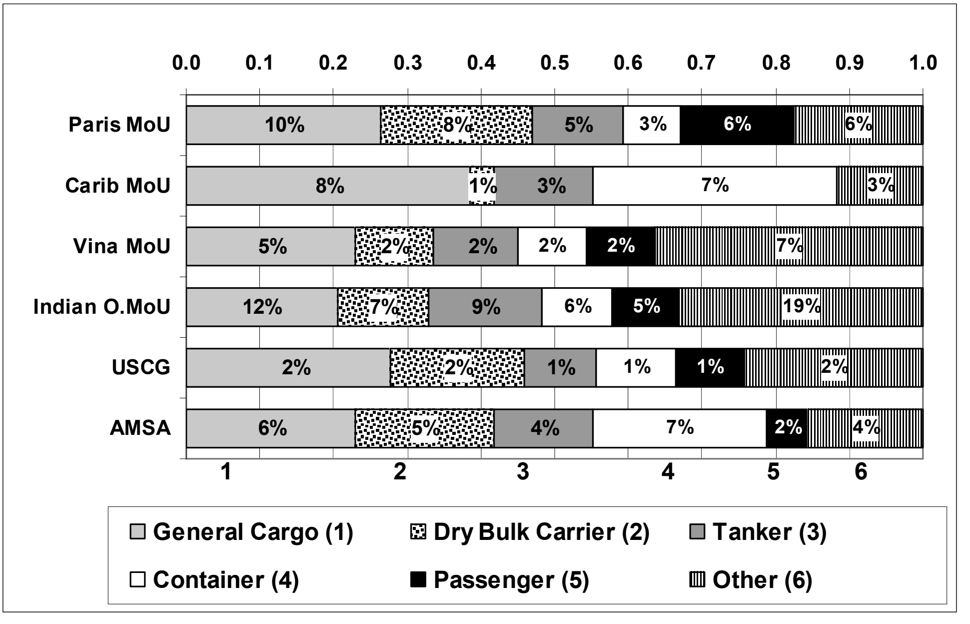


Note: compiled by author based on total PSC dataset

This clearly shows that the same ships are inspected more than once within each regime and across the regimes but only 66% of the vessels are detained once, 21% are detained twice and 13% are detained three or more times within the time period (1999 – 2004).

Most ships inspected are general cargo & multipurpose ships and dry bulk carriers followed by tankers and container ships. The USCG and AMSA show a lower amount of general cargo ships but a higher amount of dry bulk carriers for AMSA and tankers for the USCG. Detention varies per ship type and regime as can be seen in Figure 26 below.

Figure 26: Ship Types and Detention per MoU



Note: Detention percentages are individually based on total inspections for each ship type and therefore do not add up to a 100%

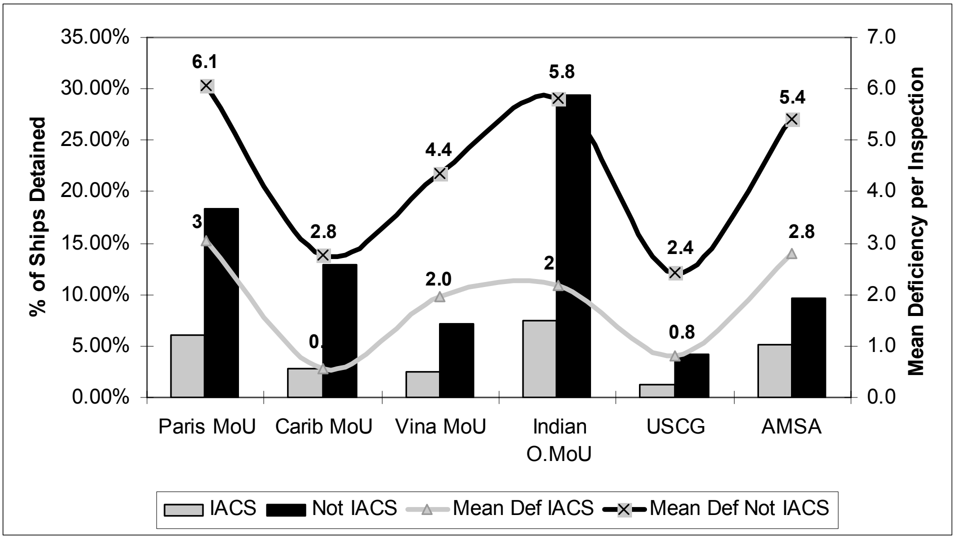
The next section will look at the key figures for classification societies which have been classified into IACS and not IACS recognized classification societies and is shown in Table 12 and visualized in Figure 27. Most ships inspected are classified by IACS recognized class in each regime (some 79 to 85%) while detention rate is higher for non IACS recognized class across all regimes. The same applies to the amount of mean deficiencies per inspection where the amount of mean deficiencies for ships classified with non IACS class is more than double to IACS class which can easily be seen by the two lines in Figure 27.

Table 12: Key Figures on Classification Societies – Total Dataset

	IACS					Not IACS				
	Total Inspections	Detentions	% Detained	% of Total MoU	Mean Deficiencies	Total Inspections	Detentions	% Detained	% of Total MoU	Mean Deficiencies
Paris MoU	77272	4688	6.07%	85.9%	3.0	12664	2317	18.30%	14.08%	6.1
Carib. MoU	545	15	2.75%	77.0%	0.6	163	21	12.88%	23.02%	2.8
Viña MoU	19029	484	2.54%	89.5%	2.0	2234	160	7.16%	10.51%	4.4
Ind. O. MoU	6530	491	7.52%	88.9%	2.2	819	241	29.43%	11.14%	5.8
USCG	44210	539	1.22%	93.8%	0.8	2898	121	4.18%	6.15%	2.4
AMSA	16954	883	5.21%	97.1%	2.8	501	48	9.58%	2.87%	5.4
Total	**164540**	**7100**				**19279**	**2908**			

Note: compiled by author based on total PSC dataset

Figure 27: Detention and Mean Deficiencies of Classification Societies



Note: compiled by author based on total PSC dataset

Table 13 gives and overview of the flag states which have been grouped into white, grey and black flag states according to the Paris MoU[76] "Black, Grey, White List" and undefined flag states as explained previously. The table shows the percentage of black, grey, white or undefined flag states which have been detained and their respective mean deficiencies per inspection.

[76] Paris MoU Black, Grey and White List for the years 2000 to 2004

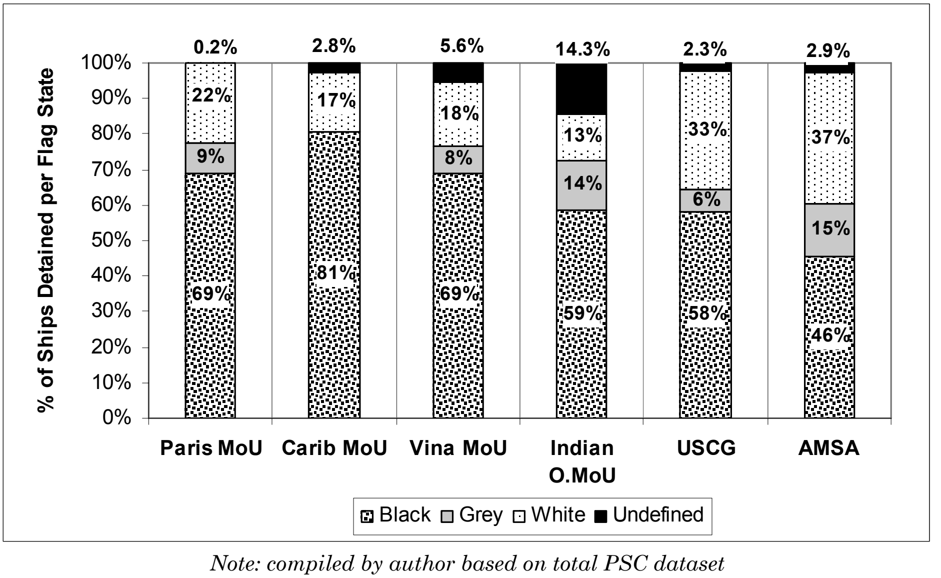
Table 13: Key Figures on Flag States – Total Dataset

	FS_Black	% Detained	Mean Deficiencies	FS_Grey	% Detained	Mean Deficiencies	FS_White	% Detained	Mean Deficiencies	FS_Undef	% Detained	Mean Deficiencies
Paris	36595	68.8%	5.1	9244	8.6%	3.0	43980	22.4%	2.2	117	0.2%	4.4
Carib.	378	80.6%	1.7	20	0.0%	0.3	229	16.7%	0.4	35	2.8%	0.4
Viña	9444	69.1%	3.0	1361	7.6%	2.6	9859	17.7%	1.3	599	5.6%	4.0
Indian	3257	58.7%	3.1	1600	13.7%	2.3	2186	13.3%	1.4	306	14.3%	7.3
USCG	18241	58.2%	1.2	3158	6.1%	1.0	24695	33.5%	0.7	1014	2.3%	1.4
AMSA	7230	45.5%	3.1	1993	14.8%	3.8	7998	36.7%	2.4	234	2.9%	5.8
Total	**75145**			**17376**			**88947**			**2305**		

Note: compiled by author based on total PSC dataset

The table is visualized in Figure 28 for the percentage of detention and in Figure 29 for the mean deficiencies. Both figures give an interesting overview on the split up of flag states. Most ships detained are black listed flag states while the USCG and AMSA also show a higher amount of detention with white listed flag states.

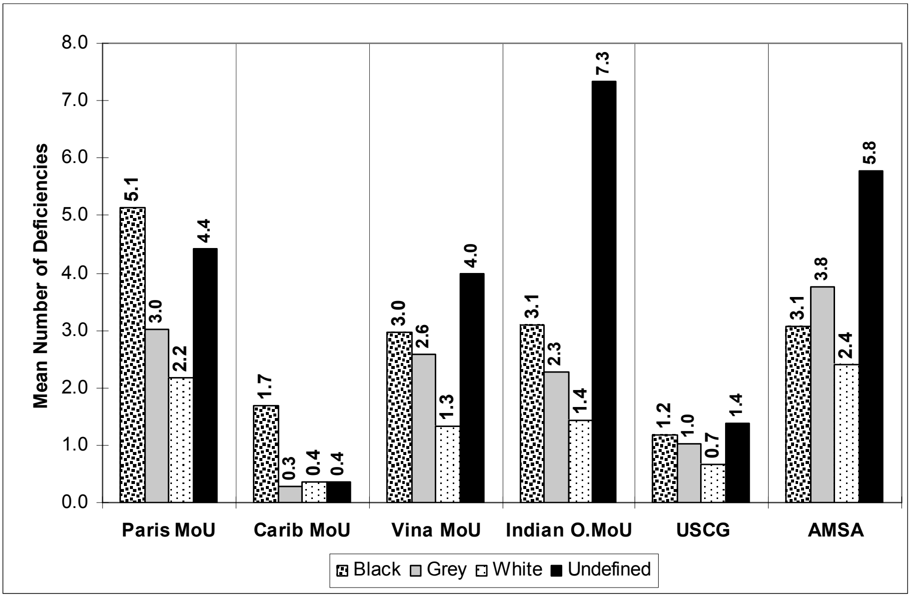
Figure 28: Percentage of Detention per Flag State and MoU



Note: compiled by author based on total PSC dataset

The amount of mean deficiencies varies between each MoU and is highest for black listed flag states and undefined flag states with the exception of AMSA and the USCG. It is almost double compared to the mean deficiencies of white listed flag states. For the Indian Ocean MoU, one can see a high percentage of undefined flag states that trade in the Indian Ocean MoU area but not in the Paris MoU area where the mean amount of deficiencies (7.3) and detention rate (14.3%) is significantly higher with the rest of the flag states.

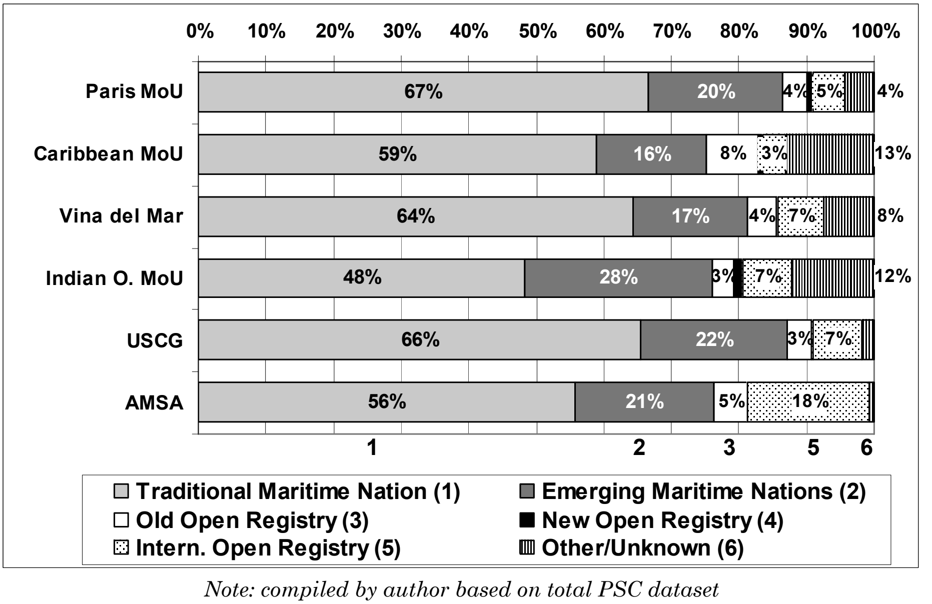
Figure 29: Mean Deficiencies per Flag State and MoU



Note: compiled by author based on total PSC dataset

Looking at the dataset with reference to the ship owner, one can see from Figure 30 that half of the vessels inspected were owned by traditional maritime nations followed by emerging maritime nations and countries from open registries.

Figure 30: Ownership of Inspected Vessels



Note: compiled by author based on total PSC dataset

This split up does vary across the regimes which also underlines the trade flows of each of these regimes and the corresponding ship profiles which serve the areas. The ship profiles will be analyzed in the next section of this chapter. The Indian Ocean MoU shows a higher percentage of owners from emerging maritime nations compared to the rest of the regimes which can be explained by the fact that the area has more regional trade using general cargo ships.

Table 14 looks into the "Document of Compliance Company" as per the ISM[77] Code. A separate merge was conducted[78] in order to combine inspections with the corresponding Document of Compliance Company and their respective country of location. Due to the amount of missing data, this variable was not used as a separate variable in the regressions to come and can only be seen as a general indication. A similar graph is produced based on the probability of casualty in part III of this thesis. The results are not presented with individual company names but by their respective country of location.

Table 14: Detention and DoC Country of Residence

Country of Residence	Not Detained	Detained	Total Inspected	% Detained
Bangladesh	32	15	47	31.9%
Cuba	60	20	80	25.0%
Papua New Guinea	23	7	30	23.3%
Algeria	16	4	20	20.0%
Romania	71	13	84	15.5%
Sri Lanka	20	3	23	13.0%
Channel Islands (British)	27	4	31	12.9%
Tunisia	23	3	26	11.5%
Syria	117	15	132	11.4%
Morocco	36	4	40	10.0%
Pakistan	27	3	30	10.0%
Brazil	129	14	143	9.8%
Egypt	37	4	41	9.8%
Lebanon	19	2	21	9.5%
Turkey	1021	99	1120	8.8%
Ukraine	384	37	421	8.8%
Portugal	55	5	60	8.3%
Argentina	69	6	75	8.0%
Latvia	181	15	196	7.7%
India	390	32	422	7.6%
Azerbaijan	233	18	251	7.2%
United Arab Emirates	294	22	316	7.0%
Bulgaria	289	20	309	6.5%
South Africa	30	2	32	6.3%
Unknown	48	3	51	5.9%
Fiji	69	4	73	5.5%
Russia	1985	115	2100	5.5%

Note: Based on total PSC dataset and more than 20 inspections, detention rate > 5%

The next chapter will produce the probability of detention and look at the differences across the regimes.

[77] International Safety Management Code
[78] Merge conducted by Lloyd's Register Fairplay

4.2. The Probability of Detention

4.2.1. Description of Model and Methodology

This model will provide the estimated probability (P) of a ship being detained based on each ship type defined previously for each safety regime. The dependent variable (y) in this case is "detained" or "not detained". In a binary regression, a latent variable y^* gets mapped onto a binominal variable y which can be 1 (detained) or 0 (not detained). 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 β represents a column vector of unknown parameters (the coefficients). The binary regression model can be derived as follows, where the same can apply to either the probability of detention or the probability of casualty (Chapter 6 and 7) later on in this thesis[79], that is,

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

The last term is equal to the cumulative distribution function of ε_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 and is defined separately with each respective model of this thesis.

Equation 1: Probability of Detention (either per regime or ship type)

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

All probabilities for the models to follow are probabilities for individual ships. To estimate the coefficients, quasi-maximum likelihood (QML)[80] 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. Since the datasets originate from different sources, a test is performed to see whether the

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

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

coefficients obtained by the regressions differ significantly from each other across the regimes. The analysis is therefore spilt up into four main steps which are visualized in Figure 31 below for better understanding.

The amount of variables and observations used in the models change across the ship types and safety regimes. In total, there are six datasets generating from five PSC regimes and six ship types as shown in Table 15 which also shows the amount of total observations for each ship dataset and the number of observations entered into the combined ship models excluding the Caribbean MoU (708 observations). The Caribbean MoU had to be excluded from the combined models due to the lack of sufficient data.

Figure 31: Visualization of Methodology for data preparation

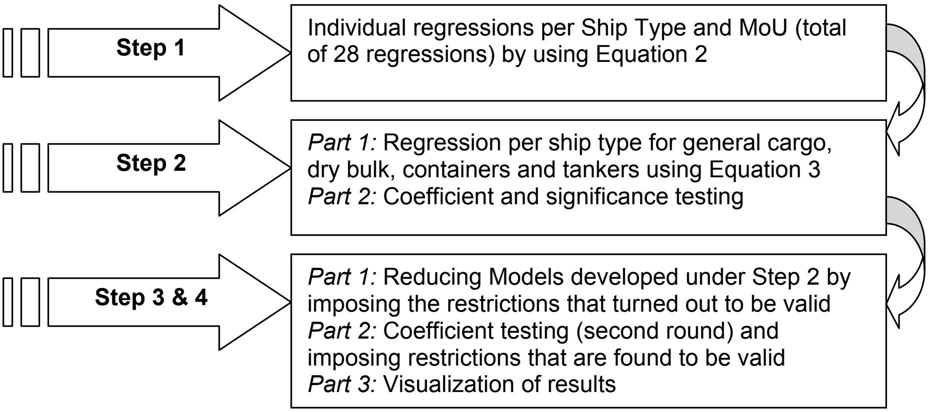


Table 15: Summary of Datasets per MoU and Ship Type

Notation	Number of Variables Start/End.	Paris MoU r=1	Carib. MoU r=2	Viña MoU r=3	Ind.O. MoU r=4	USCG r=5	AMSA r=6
General	424 to 133	GC1	One Model with all 708 observations	GC3	GC4	GC5	GC6
Dry Bulk	390 to 108	DB1		DB3	DB4	DB5	DB6
Container	245 to 72	CO1		CO3	CO4	CO5	CO6
Tanker	299 to 82	TA1		TA3	TA4	TA5	TA6
Passenger	93 to 38	PA1		PA3	PA4	PA5	PA6
Other ST	130 to 35	OT1		OT3	OT4	OT5	OT6
Total	1,581 to 468						
# of Regressions Performed		6	1	4+1	4+1	5+1	4+1
Remark concerning the regression models		All ST	Only one model	No separate model for passenger and other ships types		No separate model for PA	Same as Ind. Ocean MoU

Note: GC = general cargo, DB = dry bulk, CO= container, TA = tanker, PA = passenger, OT = other ship types

The number of variables used in the combined models is split up into the number of variables entered in the model at the beginning and the number that was left in the final models after reduction. The total number of variables for all combined models is 1,581[81] and narrows down to 468 in the final models. The four steps shown in Figure 31 are

[81] number of total multiplicative dummy variables

explained shortly here and the equations used for the regressions are given in each section respectively.

Step 1: Individual Regressions

A separate analysis is performed for each dataset listed in Table 15 which adds up to a total of 28 regressions. The models can be written in the form of Equation 1 where the term $x_i\beta$ is given in Equation 2. Table 16 gives a detailed overview of the amount of variables. The notation is as follows: i = individual ship, ℓ = variable groups, n_ℓ = total number of variables within each group of ℓ and k = index from 1 *to* n_ℓ

Equation 2: Definition of term $x_i\beta$ of Step 1 Model

$$x_i\beta = \beta_0 + \beta_1 \ln(\text{AGE}_i) + \beta_2 \ln(\text{SIZE}_i) + \sum_{k=1}^{n_3-1} \beta_{3,k}\,\text{CL}_{k,i} + \sum_{k=1}^{n_4-1} \beta_{4,k}\,\text{FS}_{k,i} + \sum_{k=1}^{n_5} \beta_5\,\text{CODE}_{k,i} + \sum_{k=1}^{n_6-1} \beta_{6,k}\,\text{PS}_{k,i} + \sum_{k=1}^{n_7-1} \beta_{7,k}\,\text{OWN}_{k,i}$$

Table 16: Binary Logistic Models: List of Total Variables Used per MoU

				Paris MoU	**Caribbean MoU**	**Viña del Mar**	**Indian Ocean MoU**	**USCG**	**AMSA**
	ℓ	***Total Number of Variables***		***nℓ***	***nℓ***	***nℓ***	***nℓ***	***nℓ***	***nℓ***
Code		**Detained**		**1**	**1**	**1**	**1**	**1**	**1**
AGE	1	Vessel Age	C	1	1	1	1	1	1
SIZE	2	Vessel Size	C	1	1	1	1	1	1
CL	3	Classification Societies	D	29	10	26	19	22	15
FS	4	Flag States	D	83	16	62	47	72	45
CODE	5	Deficiency main codes	C	26	26	26	26	26	26
PS	6	Port States or Ports *)	D	20	8	11	5	47	15
OWN	7	Ship Owner Countries	D	6	6	6	6	6	6
		Total for each MoU		**166**	**68**	**133**	**105**	**175**	**109**

C = continuous, D = dummy of categorical variables

**) for the USCG and AMSA, ports are used instead of port states*

For the step 1 model, a separate regression was performed for each ship type and MoU individually – a total of 28 regressions. For the Caribbean MoU, the dataset cannot be split up according to the ship types due to the low number of observations but one regression using the total dataset is performed including a dummy variable for each ship type. The same method is also used for passenger vessels and other ship types with a slightly modified version which will be explained under the step 2 models.

Step 2: Hypothesis and Coefficient Testing

For the step 2 model, the dependent variables except the port states were multiplied (based on the outcome of the step 1 model) by ship type and PSC regime (r) to create multiplicative dummy variables. The total dataset was then divided into six datasets (one for each ship type) and a separate regression was performed on each ship type based on Equation 3. The variables are listed in detail in Table 17 for further reference. In this equation, the notation for individual ship *i* is dropped for sake of simplification The rest of the notation is as follows: ℓ represents the variable groups, n_ℓ is total number of variables within each group of ℓ (0-7), *k* is an index from 1 to n_ℓ , *r* represents a respective PSC regime (1 to 5) and n_r is the total number of PSC regimes (5).

Equation 3: Definition of term *xβ* of Step 2 Model

$$x\beta = \sum_{r=1}^{n_r} \beta_{0,r}\mathrm{REG}_r + \sum_{r=1}^{n_r} \beta_{1,r}\ln(\mathrm{AGE})_r + \sum_{r=1}^{n_r} \beta_{2,r}\ln(\mathrm{SIZE})_r + \sum_{r=1}^{n_r}\sum_{k=1}^{n_3-1} \beta_{3,k,r}\mathrm{CL}_{k,r}$$
$$+ \sum_{r=1}^{n_r}\sum_{k=1}^{n_4-1} \beta_{4,k,r}\mathrm{FS}_{k,r} + \sum_{r=1}^{n_r}\sum_{k=1}^{n_5} \beta_{5,k,r}\mathrm{CODE}_{k,r} + \sum_{r=1}^{n_r}\sum_{k=1}^{n_6-1} \beta_{6,k,r}\mathrm{PS}_{k,r}$$
$$+ \sum_{r=1}^{n_r}\sum_{k=1}^{n_7-1} \beta_{7,k,r}\mathrm{OWN}_{k,r}$$

Table 17: Binary Logistic Models: List of Variables Used per ST - step 2 Models

		All variables are multiplicative dummies with the exception of the passenger ship and other ship types		**General Cargo**	**Dry Bulk**	**Container**	**Tanker**	**Passenger**	**Other ST**
	ℓ	***Total Number of Variables***		n_ℓ	n_ℓ	n_ℓ	n_ℓ	n_ℓ	n_ℓ
Code		**Detained**		**1**	**1**	**1**	**1**	**1**	**1**
REG	0	PSC Regime	D	5	5	5	5	5	5
AGE	1	Vessel Age	C	5	5	5	5	1	1
SIZE	2	Vessel Size	C	5	5	5	5	1	1
CL	3	Classification Societies	D	73	61	36	41	15	16
FS	4	Flag States	D	140	121	51	82	24	36
CODE	5	Deficiency main codes	C	107	101	81	93	19	18
PS	6	Port States or Ports *)	D	65	71	43	57	23	47
OWN	7	Ship Owner Countries	D	23	20	18	10	4	5
		Total for each ST		**424**	**390**	**245**	**299**	**93**	**130**

C = continuous, D = dummy of categorical variables
**) for the USCG and AMSA, ports are used instead of port states*

As mentioned earlier, the model for the passenger ships and other ship types is not based on multiplicative dummy variables due to lack of data. Those models follow the same type of model of Equation 2 based on one total dataset for all passenger vessels or other ship types respectively with the difference that no constant was used in the model but five variables indicating the respective regimes as shown in Equation 3.

In order to see if the coefficients across the PSC regimes vary, the Wald-Test for Testing Restrictions[82] was performed on the results obtained from the models and based on the following hypothesis on a subset of the matrix where ℓ represents the variable groups and n_r is the total number of PSC regimes (5).

[82] For further detail on the Wald Test for a Subset of Coefficients, please refer to Greene H.W., Fourth Edition, Econometric Analysis, Fourth Edition, page 825.

H_o: coefficients within each variable group ℓ across the PSC regimes r do not vary
$H_{a:}$ coefficients within each variable group ℓ across the PSC regimes r do vary

H_o: coefficients within each variable group ℓ across the PSC regimes r are not significant
$H_{a:}$ coefficients within each variable group ℓ across the PSC regimes r are significant

Step 3 & 4: Reduction of Models and Visualization of Results
The models per ship type are reduced to the final models as explained in Figure 31 using a significance level of 5% where the results can be seen in Table 21 for further reference. After the final reduction of the model, the coefficients were tested again in a second round applying the hypothesis developed under step 1 at a 5% significance level and restrictions were imposed when found to be valid. The last step is to visualize the results obtained under step 3 by calculating out the estimated probabilities using Equation 1.

3.3.2. Step 1 Results: Per MoU and Ship Type

Table 18 gives an overview of the classification tables of the individual regressions that were performed on each dataset by using SPSS (statistical software). The results then provide the basis for the creation of the dummy variables used in step 2.

Table 18: Step 1: Classification Tables

Ship Type	Hit Rates for detained (%)	Paris %	Carib %	Viña %	Indian %	USCG %	AMSA %
General	selected	81.4	90.9	85.3	83.5	93.3	80.8
	unselected*)	79.2	57.1	84.9	75.6	69.8	65.8
Dry Bulk	selected	81.3	90.9	85.3	90.5	88.9	81.9
	unselected*)	79.1	57.1	89.1	81.3	66.1	76.2
Container	selected	85.6	90.9	95.3	94.4	90.9	80.8
	unselected*)	68.5	57.1	80.0	57.1	64.7	75.0
Tanker	selected	82.3	90.9	91.2	90.7	87.0	81.0
	unselected*)	81.8	57.1	79.2	84.1	66.7	65.4
Passenger	selected	77.4	90.9	86.9	86.8	89.2	78.0
	unselected*)	80.7	57.1	89.6	76.2	84.4	76.0
Other ST	selected	85.6	90.9	86.9	86.8	84.4	78.0
	unselected*)	80.0	57.1	89.6	76.2	68.3	76.0

**) unselected means out of sampling forecasting which is an option used in SPSS*

The cut off rate used for each of the models is based on the detention rate which varies accordingly per MoU and ship type and is listed in Table 19 for each ship type and MoU and for each ship type as a total. The latter is used in step 2 to produce the classification tables. One can see that the hit rate for detained vessels varies and that the Caribbean Model due to its low number of observations shows less predictive accuracy with 57% hit rate for out of sample forecasting. Container vessels also show lower hit rates for all MoU's compared to the other main ship types (general cargo, dry bulk and tankers) but in general, the hit rates are found to be acceptable for the amount of data and variables.

Based on these outcomes, multiplicative dummy variables are computed for each variable and ship type (e.g. ship type general cargo Paris MoU*Classification Society ABS) and the datasets for the ship types of each MoU (e.g. all general cargo ships) are aggregated to one dataset which ends of with 4 datasets (general cargo, dry bulk, container and tanker) to be the basis for the next step.

Table 19: Cut Off Rates (based on observed detention rate) per ST and MoU

		Cut Off Rate for Classification Table					
Ship Types	**Total**	**Paris**	**Carib**	**Viña**	**Indian**	**USCG**	**AMSA**
General Cargo	0.080	0.097	0.051*)	0.046	0.121	0.023	0.065
Dry Bulk	0.046	0.076	0.051*)	0.021	0.072	0.015	0.053
Container	0.020	0.029	0.051*)	0.019	0.056	0.009	0.066
Tanker	0.031	0.046	0.051*)	0.023	0.090	0.008	0.038
Passenger	0.034	0.057	0.051*)	0.03*)	0.099*)	0.014*)	0.053*)
Other Ship Types	0.037	0.064	0.051*)	0.03*)	0.099*)	0.020	0.053*)

**) regression based on total dataset*

3.3.3. Step 2 Results: Coefficient Testing (Performed in 2 Rounds)

Based on Equation 3, the models are estimated and the coefficients are tested according to the set of hypotheses explained earlier at a 5% significance level. The result can be seen in Table 21 for detailed reference. The testing was performed in two rounds – first if the coefficients vary significantly across the MoUs and second, if they are zero. One of the most interesting findings in performing the testing is that the main differences across the regimes are based on the port states and the individual deficiency codes and not necessarily the flag states or classification societies. The next sections will impose the restrictions that were found to be valid and will after reducing the models and performing a second test round; visualize the main findings for the probability of detention across the regimes.

3.3.4. Step 3 Results: Final Models per Ship Type

As a first step, the models were estimated without QML[83] and with QML using Huber/White standard errors and covariance at the time the program first found a solution. The results were compared to identify significant differences in the coefficients and the results can be seen in Table 20 which lists the variables at the time the matrix first solved, the amount of variables which changed significance and the amount of variables which are changed in the final models.

Table 20: Variables changed based on QML versus non QML estimation

Variables at the time matrix first solved	Total Variables	#of Variables changed	% Variables changed	Final # of Variables changed in reduced Model
General Cargo	424	15	3.6%	9
Dry Bulk	390	35	9.0%	2
Container	245	18	7.4%	2
Tanker	299	25	8.4%	1
Passenger	93	4	4.3%	0
Other Ship Types	130	6	4.7%	0

[83] Quasi Maximum Likelihood – Huber/White standard error & covariance

Table 21: Step 2: Results – Testing of Equality of Coefficients across the Regimes

Table 21 – part 1		General Cargo					Dry Bulk					Tanker					Container				
		round 1			round 2		round 1			round 2		round 1			round 2		round 1			round 2	
Code	Variable	# of variables	Test of Equality of Coefficients	Significance	# of variables	Test of Equality of Coefficients	# of variables	Test of Equality of Coefficients	Significance	# of variables	Test of Equality of Coefficients	# of variables	Test of Equality of Coefficients	Significance	# of variables	Test of Equality of Coefficients	# of variables	Test of Equality of Coefficients	Significance	# of variables	Test of Equality of Coefficients
	Age	5	0.6373	0.0000			5	0.0982	0.0000			5	0.0710	0.0000			5	0.8234	0.1127		
	Size	5	0.0088	0.0000	3	0.5480	5	0.1023	0.0091			5	0.3409	0.0575			5	0.4766	0.0014		
ABS	American Bureau of Shipping	5	0.0772	0.1308			5	0.5606	0.4055			5	0.4414	0.5769			4	0.3808	0.5311		
BV	Bureau Veritas	5	0.1724	0.2491			5	0.0844	0.1323			4	0.5116	0.4663			4	0.2712	0.2489		
CCS	China Classification Society	3	0.6979	0.4107			4	0.6253	0.5339												
CRR	Croatian Register of Shipping						2	0.0821	0.1120												
DNV	Det Norske Veritas	5	0.0103	0.0398	2	0.0678	5	0.5740	0.5134			5	0.3149	0.0163			3	0.0215	0.0520		
GL	Germanischer Lloyd	5	0.0950	0.1329			4	0.7495	0.8373			4	0.0819	0.1147			5	0.1782	0.2770		
HIN	Honduras Inter. Naval Survey IB	2	0.2920	0.5739																	
IBS	Isthmus Bureau of Shipping	2	0.3591	0.6488																	
INS	Intern. Naval Surveys Bureau	2	0.5745	0.3432			2	0.0817	0.1699												
IRS	International Register of Shipping	3	0.1126	0.1850																	
KRS	Korean Register of Shipping (South)	4	0.0429	0.0187			4	0.4843	0.0814								2	0.7279	0.0648		
LLR	Lloyds Register of Shipping (UK)	4	0.0225	0.0118	3	0.0166	5	0.1848	0.1138			5	0.3123	0.0513			4	0.0048	0.0086		
NCL	No Class Recorded	2	0.5890	0.6730			2	0.3809	0.2977								2	0.9436	0.7701		
NKK	Nippon Kaiji Kyokai (Japan)	5	0.0602	0.0487	2	0.3993	5	0.4899	0.2805			5	0.2254	0.1098			4	0.1388	0.1688		
PRS	Polski Rejestr Statkow (Poland)	4	0.0039	0.0095			4	0.2166	0.1854												
RIN	Registro Italiano Navale (Italy)	4	0.1280	0.1920			3	0.8010	0.8510			4	0.4145	0.3450			2	0.8327	0.5954		
RMS	Russian Maritime Register of Shipping	5	0.4846	0.4135			4	0.4306	0.4947			4	0.1455	0.2370							
AG	Antigua and Barbuda	4	0.4843	0.1403			2	0.0700	0.1910								4	0.5624	0.6223		
AN	Antilles Netherland	3	0.9356	0.1754																	
BO	Bolivia	3	0.0054	0.0018																	

Table 21 – part 2		General Cargo					Dry Bulk					Tanker					Container				
		round 1			round 2		round 1			round 2		round 1			round 2		round 1			round 2	
Code	Variable	# of variables	Test of Equality of Coefficients	Significance	# of variables	Test of Equality of Coefficients	# of variables	Test of Equality of Coefficients	Significance	# of variables	Test of Equality of Coefficients	# of variables	Test of Equality of Coefficients	Significance	# of variables	Test of Equality of Coefficients	# of variables	Test of Equality of Coefficients	Significance	# of variables	Test of Equality of Coefficients
BS	Bahamas	5	0.1997	0.1331			5	0.8318	0.2093			4	0.2212	0.1177			4	0.6959	0.8277		
BZ	Belize	2	0.8025	0.5183																	
BR	Brazil						3	0.0053	0.0015	2	0.0000										
CN	China	3	0.2580	0.4361			4	0.9370	0.8278												
CY	Cyprus	5	0.3959	0.0075	3	0.2039	5	0.4504	0.0045			5	0.1961	0.1088			5	0.5748	0.6927		
DE	Germany																2	0.9846	0.4926		
DK	Denmark	4	0.7012	0.7039								3	0.1124	0.0758							
EG	Egypt						2	0.3386	0.0721												
ET	Ethiopia	2	0.5550	0.8109																	
GE	Georgia	2	0.2856	0.0056																	
GI	Gibraltar	2	0.3590	0.0319																	
GR	Greece	2	0.4302	0.5718			5	0.8824	0.2218			3	0.0255	0.0005	2	0.4256	2	0.5040	0.0844		
HK	Hong Kong	4	0.0185	0.0139			5	0.3508	0.1159			3	0.3795	0.5830							
HR	Croatia						3	0.0896	0.1644												
IM	Isle of Man	2	0.4037	0.6447			2	0.2903	0.0536												
IN	India						3	0.9131	0.0156			3	0.3649	0.2113							
IR	Iran	2	0.6848	0.0898			2	0.7926	0.0426												
IT	Italy						3	0.5387	0.0231			2	0.6204	0.6199							
KH	Cambodia	3	0.2656	0.0010																	
KP	North Korea	2	0.2083	0.0071																	
KR	South Korea						3	0.4980	0.0036												
KY	Cayman Islands	3	0.9684	0.1840			4	0.5588	0.0644			3	0.5814	0.5005							
LR	Liberia	5	0.3578	0.3847			5	0.4012	0.0426			5	0.0677	0.0787	2	0.6365	4	0.3077	0.2907		
MH	Marshall Islands	3	0.6486	0.7862			4	0.7396	0.1916			5	0.4354	0.5560							
MT	Malta	5	0.2081	0.0116			5	0.1607	0.0018			4	0.0059	0.0004	4	0.5280	3	0.8521	0.2151		
MY	Malaysia						3	0.6034	0.0262			3	0.4863	0.3045			2	0.6049	0.0711		
NL	Netherlands	4	0.7683	0.2810			2	0.1530	0.0105			2	0.6718	0.5635			3	0.2780	0.2876		
NO	Norway	3	0.5029	0.6256			3	0.3497	0.3450			4	0.0069	0.0137							
PA	Panama	5	0.0271	0.0000	4	0.0789	5	0.5310	0.0091			5	0.0002	0.0000	2	0.6303	5	0.2594	0.0906		
PH	Philippines	4	0.2720	0.0578			4	0.6348	0.0255												
PL	Poland						2	0.0758	0.0310												
RU	Russian Federation	2	0.8107	0.0001								2	0.1928	0.0577							

Table 21 – part 3		General Cargo					Dry Bulk					Tanker					Container				
		round 1			round 2		round 1			round 2		round 1			round 2		round 1			round 2	
Code	Variable	# of variables	Test of Equality of Coefficients	Significance	# of variables	Test of Equality of Coefficients	# of variables	Test of Equality of Coefficients	Significance	# of variables	Test of Equality of Coefficients	# of variables	Test of Equality of Coefficients	Significance	# of variables	Test of Equality of Coefficients	# of variables	Coefficient Testing	Significance	# of variables	Test of Equality of Coefficients
SE	Sweden	3	0.0842	0.1747																	
SG	Singapore	2	0.7601	0.4617			4	0.5192	0.0097			4	0.3096	0.0103			4	0.2952	0.4082		
TH	Thailand	3	0.7485	0.5057			3	0.1885	0.3382												
TR	Turkey	2	0.1148	0.0000			5	0.8337	0.0200												
TW	Taiwan						2	0.7650	0.0936												
UA	Ukraine	2	0.8116	0.0008			2	0.4498	0.0890												
UK	United Kingdom											2	0.4595	0.4395			2	0.9237	0.7673		
VC/SV	St. Vincent & the Grenadines	5	0.0398	0.0000	2	0.0544	5	0.1528	0.0541			2	0.1568	0.0013			2	0.0005	0.0001		
VU	Vanuatu	4	0.2089	0.0715																	
100	Ship's certificates and documents	5	0.0000	0.0000	3	0.0010	5	0.0000	0.0000	4	0.0709	5	0.6376	0.0000			5	0.6486	0.0000		
200	Crew certificates	5	0.0000	0.0000	5	0.0000	5	0.0000	0.0000	4	0.0000	5	0.0000	0.0000	4	0.0000	5	0.0000	0.0000	4	0.0045
300	Accommodation	5	0.0535	0.0024			5	0.0601	0.6440	2	0.7453	4	0.0261	0.0117	2	0.0212	3	0.0182	0.0101		
400	Food and catering	4	0.1765	0.2878			4	0.1936	0.1469			3	0.9917	0.6672			2	0.2989	0.0357		
500	Working spaces and accident prevention	4	0.1480	0.0028	3	0.0056	3	0.3941	0.4846			2	0.4734	0.6762			2	0.8167	0.4619		
600	Life saving appliances	5	0.0010	0.0000	3	0.0056	5	0.0000	0.0000	5	0.0000	5	0.0000	0.0000			5	0.4078	0.0000		
700	Fire Safety measures	5	0.0040	0.0000	4	0.0012	5	0.0000	0.0000	5	0.0000	5	0.3463	0.0000			5	0.0000	0.0000	3	0.0513
800	Accident prevention (ILO147)	5	0.4718	0.5230			5	0.0218	0.0420			3	0.2629	0.4037			2	0.3488	0.6226		
900	Structural Safety	5	0.0000	0.0000	5	0.0000	5	0.0064	0.0000	4	0.6498	5	0.0423	0.0000	3	0.0640	5	0.0077	0.0000	4	0.0112
1000	Alarm signals	5	0.6793	0.0000			5	0.8309	0.8068			3	0.6520	0.0938							
1100	Cargoes	5	0.0006	0.0000	3	0.0003	5	0.2135	0.1793			3	0.7232	0.1457			4	0.5996	0.4934		
1200	Load lines	5	0.0000	0.0000	4	0.8410	5	0.1465	0.0000	2	0.2331	5	0.3015	0.0003			5	0.1293	0.0000		
1300	Mooring arrangements (ILO 147)	5	0.0490	0.0029	2	0.5029	5	0.5774	0.6491			5	0.0009	0.0000	2	0.0012	4	0.2829	0.2674		
1400	Propulsion & aux.	5	0.1237	0.0000	3	0.1201	4	0.2512	0.0000			5	0.3776	0.0004			5	0.0905	0.0000	3	0.8884
1500	Safety of navigation	5	0.0001	0.0000	3	0.0666	5	0.0116	0.0004	2	0.2082	5	0.2830	0.0311			5	0.3467	0.4816		
1600	Radio communications	5	0.0316	0.0000	4	0.0055	5	0.0082	0.0000	4	0.0004	5	0.0022	0.0017	3	0.0000	4	0.7991	0.0000		
1700	MARPOL annex I (Oil)	5	0.0094	0.0000	4	0.2540	5	0.0125	0.0000	5	0.0167	5	0.0034	0.0000	3	0.0000	5	0.0134	0.0000	4	0.2317
1800	Gas and chemical carriers											4	0.0052	0.0005	2	0.2751					
2000	Operational deficiencies	5	0.0021	0.0035	3	0.0005	4	0.0000	0.0000			5	0.0174	0.0144			4	0.5767	0.4367		

Table 21 – part 4		General Cargo					Dry Bulk					Tanker					Container				
		round 1			round 2		round 1			round 2		round 1			round 2		round 1			round 2	
Code	Variable	# of variables	Test of Equality of Coefficients	Significance	# of variables	Test of Equality of Coefficients	# of variables	Test of Equality of Coefficients	Significance	# of variables	Test of Equality of Coefficients	# of variables	Test of Equality of Coefficients	Significance	# of variables	Test of Equality of Coefficients	# of variables	Test of Equality of Coefficients	Significance	# of variables	Test of Equality of Coefficients
2100	MARPOL related op. def.	4	0.1970	0.2691			3	0.7468	0.8013			2	0.6432	0.6629			2	0.5142	0.0001		
2200	MARPOL annex III (Package)																				
2300	MARPOL annex V (Garbage)	3	0.4652	0.0477			2	0.0544	0.0390			2	0.0118	0.0024	2	0.0015	2	0.1572	0.3281		
2500	ISM related deficiencies	5	0.0000	0.0000	4	0.0000	5	0.0000	0.0000	4	0.0000	4	0.0000	0.0000	3	0.1034	4	0.0020	0.0000	3	0.0001
OOR	Owner from Old Open Registry Country	4	0.0158	0.0341			3	0.6703	0.7165			3	0.1912	0.3330			2	0.8593	0.0010		
IOR	Owner from Intern. Open Registry Country	5	0.0796	0.0888	2	0.4555	4	0.1134	0.0954								3	0.0025	0.0042		
TMN	Owner from Traditional Maritime Nation	5	0.0173	0.0151	2	0.0079	5	0.8201	0.4477			4	0.4494	0.2132			5	0.0192	0.0339		
EMN	Owner from Emerging Maritime Nation	5	0.0325	0.0600			5	0.4915	0.4562								5	0.0215	0.0416		
UNK	Owner Unknown	4	0.0040	0.0009	2	0.0019	3	0.0053	0.0145			3	0.4341	0.4774			3	0.0146	0.0311		

Note: the number of variables depicts the number of variables that were in the test in each round. The first round of testing was performed after the program found a solution the first time and the second round of testing was performed after the model was reduced to only significant variables.

One can see that the significance of some of the variables changed especially for the dry bulk model. To give a certain allowance for a possible misspecification of the assumption of the underlying function, QML was used for the final models and both probit and logit was estimated and the results are shown inTable 22.

The table lists the number of observations that were used in each model, outliers that were identified and eliminated, the Mc Fadden[84] R^2 and the hit rates with the respective cut off values used to produce the of the classification tables for each model, the Hosmer-Lemeshow-Statistic (HL) and its p-value. The HL test is a goodness of fit test which compares the expected values with the actual values by group. Its null hypothesis *(H_o)* assumes little difference of the expected versus actual values and therefore a good fit of the model to the data. The alternative hypothesis (H_a) represents not a good fit of the model to the data.

Table 22: Summary of Key Statistics and Classification Table

	General		Dry Bulk		Container	
# observations in final model	0 =	60893	0 =	45571	0 =	17785
	1 =	5580	1 =	2206	1 =	426
	Total=	66473	Total=	47777	Total=	18211
# outliers	132		184		6	
Cut Off	0.0842		0.0462		0.0240	
	LOG	PRO	LOG	PRO	LOG	PRO
Mc Fadden R2	0.433	0.438	0.411	0.419	0.448	0.459
% Hit R. y=0	87.59	86.39	87.55	86.84	90.49	90.12
% Hit R. y=1	82.26	83.33	84.18	85.58	85.92	87.32
% Hit R. Tot	87.14	86.12	87.39	86.78	90.38	90.05
HL-Stat. df=8	130.74	51.83	67.16	47.45	17.82	15.28
p-value	0.0000	0.0000	0.0000	0.0000	0.0226	0.0539
	Tanker		Passenger		Other ST	
# observations in final model	0 =	32985	0 =	5907	0 =	9699
	1 =	1060	1 =	211	1 =	374
	Total=	34045	Total=	6118	Total=	10073
# outliers	82		12		4	
Cut Off	0.0312		0.0345		0.0372	
	LOG	PRO	LOG	PRO	LOG	PRO
Mc Fadden R2	0.424	0.435	0.332	0.427	0.388	0.399
% Hit R. y=0	88.81	88.39	84.54	86.58	88.20	87.74
% Hit R. y=1	86.60	87.26	86.73	90.45	83.69	86.36
% Hit R. Tot	88.74	88.36	84.62	86.70	88.04	87.69
HL-Stat. df=8	31.15	19.74	7.53	4.94	16.38	10.55
p-value	0.0001	0.0113	0.4803	0.7640	0.0372	0.2284

The Mc Fadden R^2 and the hit rate are acceptable for the amount of observations used in each model. Outliers were identified at each step and the model was reduced at a 5% significance level where most variables are significant at a 1% level. The results of some of the HL statistic indicate that there is not a good fit of the model which can be explained due to the very large amount of observations. Regardless of this statistic, it is

[84] The Mc Fadden R2 is not provided by the model automatically and was therefore computed separately. For further details on this statistics, refer to Franses, P.H. and Paap, R. (2000). *Quantitative Models in Marketing Research.*

found that the result is good enough to be used as the hit rates are very good. Not much difference between logit and probit can be identified and the logit models are used for the visualization of the results. The remaining statistics of the resulting final models can be found in Appendix 7 to Appendix 12 for further reference.

3.3.5. Step 4: Visualization of Results

This section visualizes the findings in graphical form through the creation of ship profiles and the grouping of the main deficiency codes into eight main deficiency groups shown in Table 23. The grouping of the codes reflects the similarity of the deficiency codes by their nature (e.g. operational deficiencies, management related deficiencies, crew related deficiencies, etc.). The number in brackets next to the deficiency group represents the number that is used in the graphs later on in this chapter to facilitate differentiation of the graphs in black and white versus color.

Table 23: Grouping of Deficiency Codes for Visualization

Deficiency Main Group	**Description of Codes within the Main Group**	
Certificates (1)	Ship's certificates	Code_0100
	Crew certificates	Code_0200
Safety & Fire Appliances (2)	Life saving appliances	Code_0600
	Fire safety measures	Code_0700
	Alarm Signals	Code_1000
Equipment/Machinery (3)	Propulsion & Aux. Machinery	Code_1400
Ship & Cargo Operations (4)	Carriage of Cargo & Dang. Goods	Code_1100
	MARPOL I: SOPEP, Oil Record Book	Code_1700
	Oil, Chemical Tankers and Gas Carriers	Code_1800
	MARPOL II: P&A Manual, Cargo Rec.B.	Code_1900
	SOLAS related operational deficiencies	Code_2000
	MARPOL related operational deficiencies	Code_2100
	MARPOL III: Packaging, Documentation	Code_2200
	MARPOL V: Garbage Management	Code_2300
Working & Living Conditions (5)	Accommodation	Code_0300
	Food & Catering	Code_0400
	Working spaces, accident prevention	Code_0500
	Accident prevention	Code_0800
	Mooring Arrangements	Code_1300
Stability/Structure (6)	Stability/Structure/Equipment	Code_0900
	Load Lines	Code_1200
	Bulk Carriers, additional safety measures	Code_2600
Navigation/Communication (7)	Safety of Navigation	Code_1500
	Radio communications	Code_1600
Management (8)	ISM related deficiencies	Code_2500
	ISPS related deficiencies (not used)	Code_2700

In visualizing the results, three approaches are used. First, each ship type is analyzed for each MoU. Second, the difference in the contribution towards the probability of detention is shown across the MoU's and finally, an overall view is presented based on average probabilities.

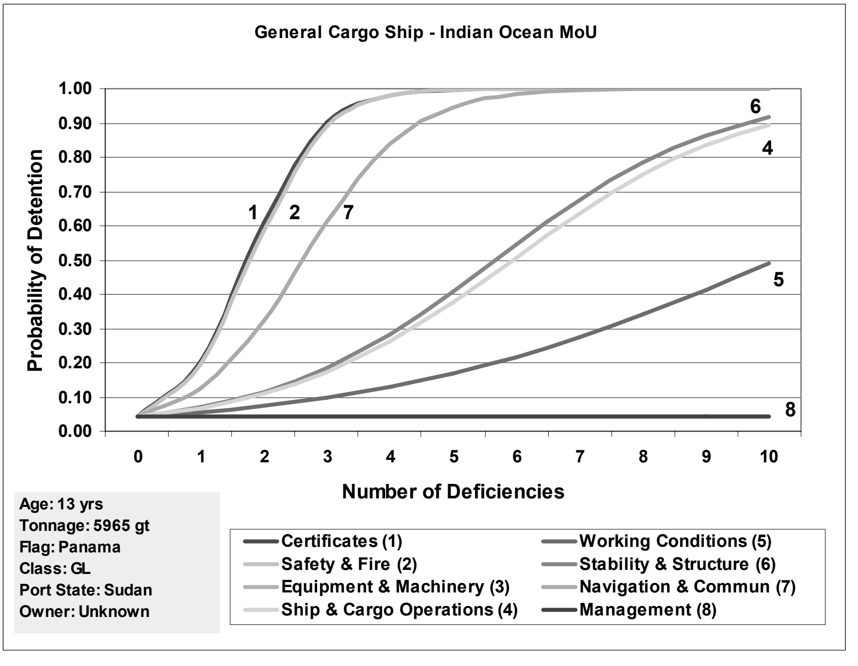
3.3.6 Individual Results per Ship Type

In order to visualize the results of the regressions, ship profiles are created and the corresponding probability of detention is computed and shown in Figure 32 to Figure 37 for each ship type and MoU. Due to the amount of graphs, only one ship type per MoU is shown here and the rest can be seen in Appendix 14 to Appendix 17.

Typical ship profiles for each ship type are created and the probability of detention is calculated out based on the number of deficiencies for each deficiency category. The steeper the curve of the graph, the higher the contribution of the deficiency group towards the probability of detention. In essence, it reflects the ship profiles that trade in the area as well as the emphasis that was placed on certain deficiencies during an inspection.

For the general cargo ship that can be seen in Figure 32 for the Indian Ocean MoU, 3 deficiencies in the area of certificates lead to a high probability of detention (0.9). The deficiency groups related to safety and fire and to certificates show the highest contribution towards detention followed by deficiencies related to navigation and communications, stability and structure and ship and cargo operations.

Figure 32: Probability of Detention - General Cargo



Overall, the graphs show the differences between the regimes and the ship types. For the dry bulk carrier in Figure 33 for AMSA, the highest contribution can be found with ISM related deficiencies (Management) followed by certificates and ship and cargo operations. ISM related deficiencies reflect how the safety management system is implemented onboard while the deficiency group ship and cargo operations reflect the actual execution of the management system. The same applied for one of the most important deficiency groups – safety and fire appliances.

Figure 33: Probability of Detention – Dry Bulk

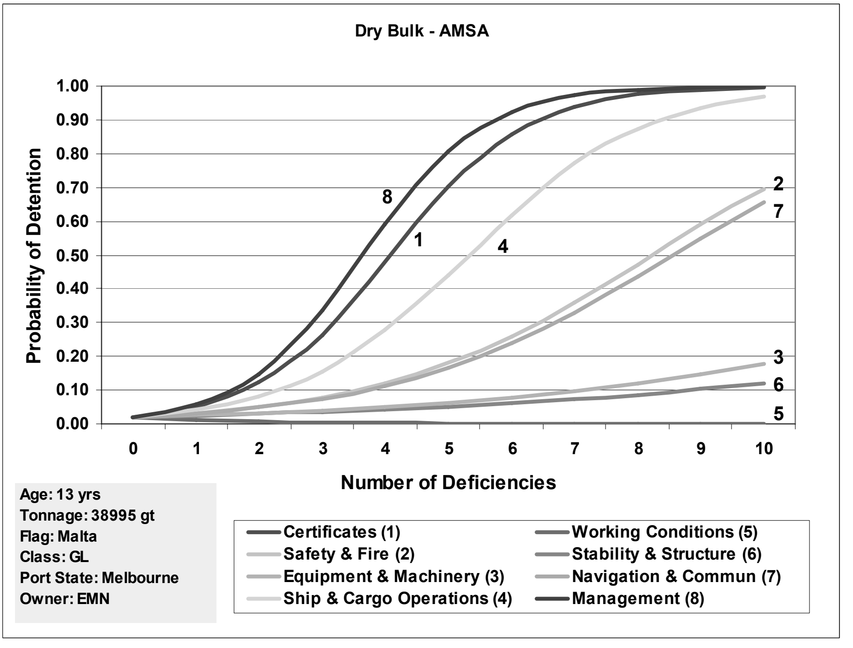


Figure 34: Probability of Detention – Tankers

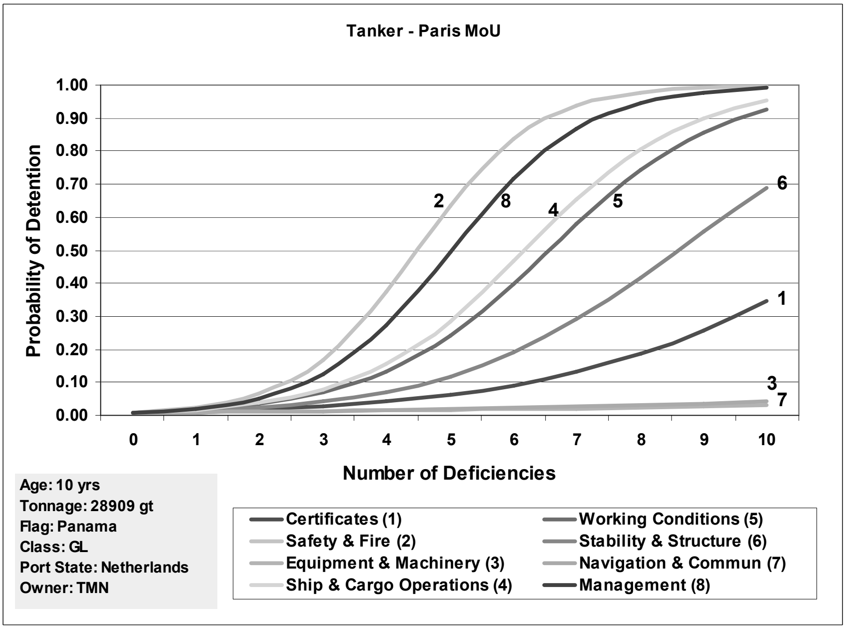
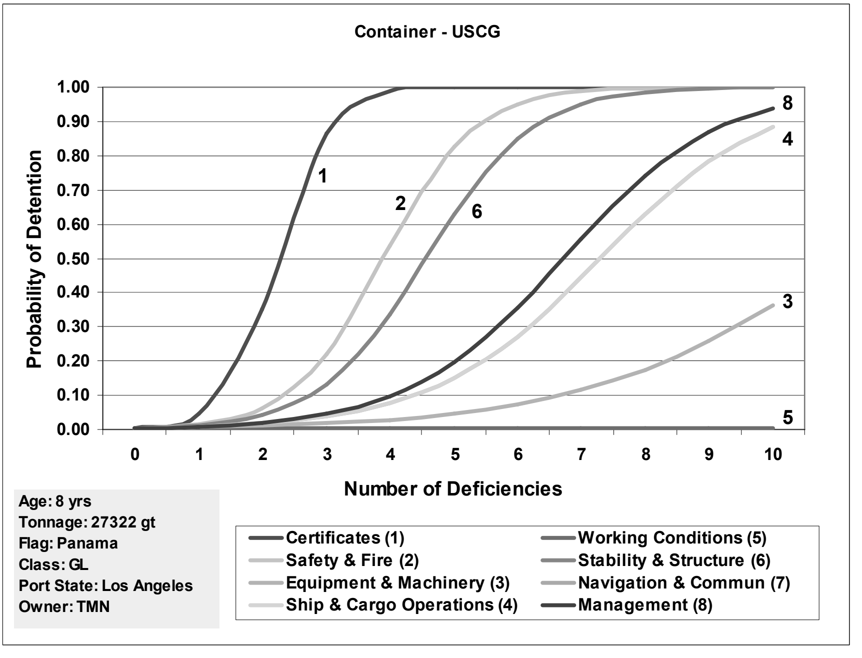


Figure 34 shows the tanker for the Paris MoU region and Figure 35 shows the container vessel for the USCG. For the first graph, the most important deficiency group is safety and fire appliances followed by ISM related deficiencies (Management) and ship and cargo operations. The picture is similar to the AMSA picture for dry bulk carriers. What is interesting to notice is that the group living and working conditions also show a higher contribution than with other ship types which is counter intuitive since tankers seem to have a better ship profile to start with than for instance general cargo ships or dry bulk carriers.

Figure 35: Probability of Detention – Container



For the container vessel as shown in Figure 35 , the most important deficiency group is the certificates followed by the group safety and fire and then stability and structure. The last group is also interesting to see for this particular ship type and there is no real explanation on why this particular deficiency group would show a relative high contribution. Container ships are normally younger and better maintained vessels.

Figure 36 and Figure 37 show the results for the passenger vessel and other ship types. The models for those two groups were produced under a slightly different method due to the lack of observations and detention and are therefore not as accurate as the previous models. What is interesting to see is a relatively high contribution of work related deficiencies which might mean that these areas are inspected more with passenger vessels and a relatively low contribution of safety & fire appliances related deficiencies which might indicate that passenger vessels perform better in this area than other vessels due to the relative importance and stringent requirements thereof.

The results of the other ship types are similar to general cargo, dry bulk and tankers but also show a higher contribution towards detention with codes in the area of working and living conditions. This group of ship types consists primarily of offshore supply vessels and mobile offshore vessels, special purpose vessels and factory ships which might explain the higher contribution of working related deficiencies.

Figure 36: Probability of Detention – Passenger Vessels

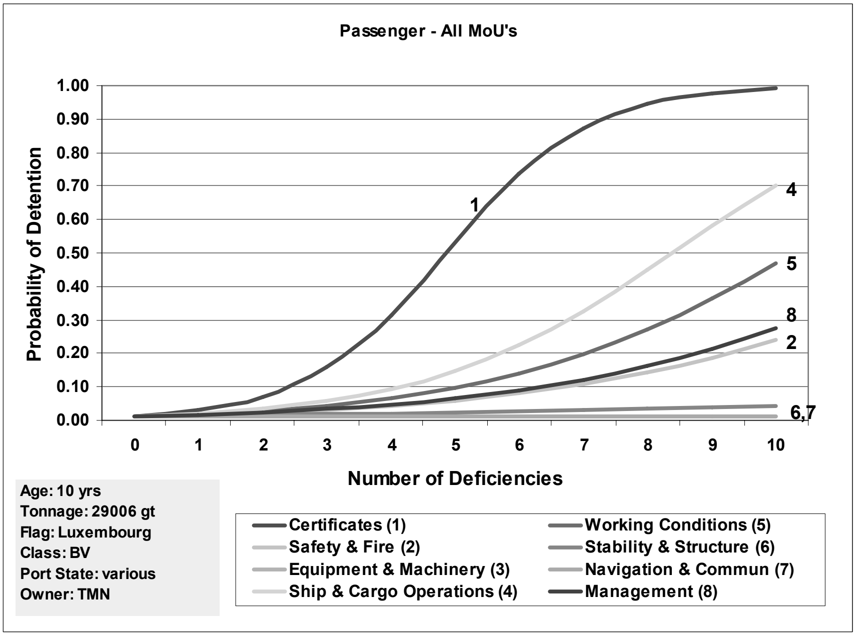
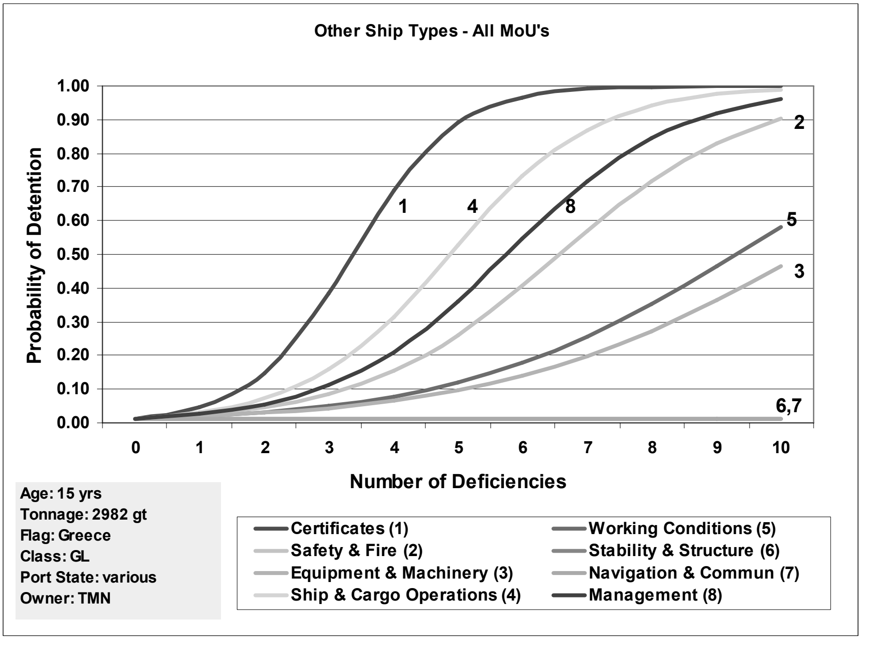


Figure 37: Probability of Detention – Other Ship Types



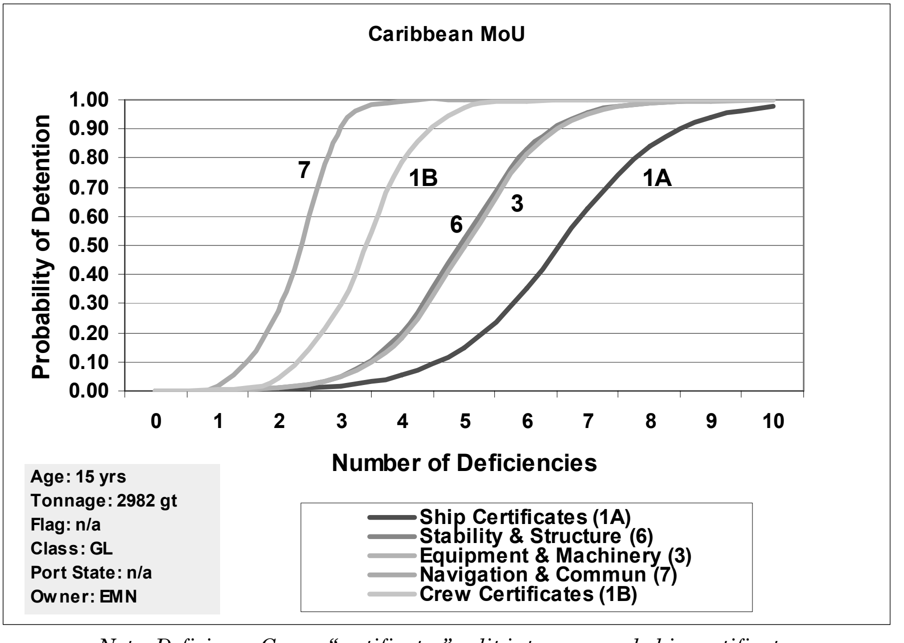
The next section will show the results for the regression that was performed for the Caribbean MoU which had to be excluded from the rest of the regressions due to the insufficient amount of data per ship type.

3.3.7. Results for the Caribbean MoU

Due to the lack of data, this section is difficult to analyze for the Caribbean MoU. Only one model for the whole dataset could be produced where few variables (deficiency codes) and one classification society remains significant. The statistics can be found in Appendix 13 for further reference. No difference can be seen based on flag, size or age or ship type. Owners from traditional maritime nations and emerging maritime nations seem to perform better than the other owner groups.

What is interesting to see is the high contribution for the deficiency code 1500 (safety of navigation) followed by crew certificates (200) and the deficiency groups for stability and structure and equipment & machinery. Ship certificates (100) also show a relatively high contribution. The rest of the deficiency codes are not significant.

Figure 38: Probability of Detention – Caribbean MoU



Note: Deficiency Group "certificates" split into crew and ship certificates

Since it is difficult to analyze each of the graphs individually and to compare the differences, the next section will produce a series of graphs that allows doing so and should visualize the differences of the contributions of the deficiencies across the regimes.

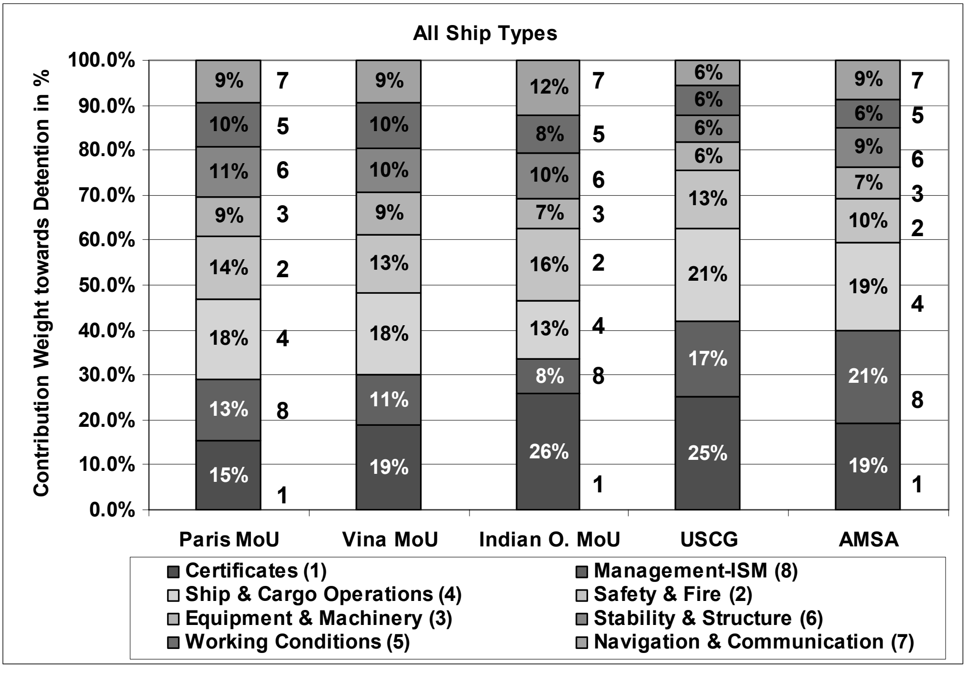
3.3.8. Differences in Deficiencies across the MoU's

Figure 39 provides an overall overview of the percentage contribution of the deficiency groupings towards the probability of detention per regime. The same basic ship profile was used for all regimes in order to calculate the probability of detention. The resulting factor is then converted into a percentage to the total weight of all deficiency codes towards the probability of detention. By giving all ship types the same basic risk profile and by assuming that the total weight towards the probability of detention based on the deficiency codes is a 100%, the probabilities obtained through the deficiencies codes is converted to a percentage weight. The resulting percentages not only take into account the differences within each regime but also show the percentage weights of the deficiency groups across the regimes.

The graph below can be read as follows. From the total contribution of the deficiency groups towards detention for the USCG, 25% of weight towards detention derives from deficiencies within the area of certificates, 17% within the area of the ISM code (Management), 21% from deficiencies within ship & cargo operations etc. The lower the percentage, the lower the overall weight of this deficiency group towards detention.

The graph should not be understood as a ranking of quality of the inspections but it should merely give an insight into the different emphasizes with respect to the deficiencies and reflects to a certain extent the average performance of all ships. Looking at the overall graph in total, one can see that there are some differences across the regimes but these are quite comparable when aggregated by all ship types.

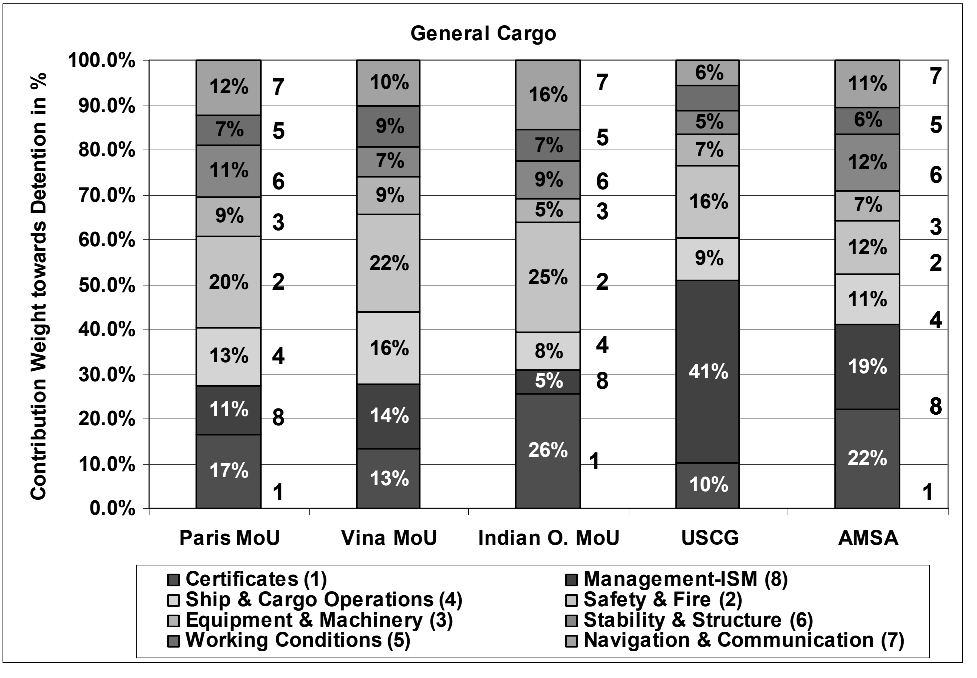
Figure 39: Contribution Weight towards Detention: All Ship Types



The actual differences can best be seen when looking at each ship type separately and is shown in Figure 40 to Figure 44. All graphs show a higher percentage for the deficiency groups' certificates, ship and cargo operations, the ISM code and safety & fire which is not surprisingly.

The weight of these groups changes with respect to the regimes which might reflect the different emphasis and the trade flows. *Certificates* are always inspected and are one of the underlying factors for constituting "clear grounds". *Safety and fire appliances* are always part of the round that is performed during an inspection where life boats and their equipment, launching equipment, lifejackets, immersion suits and fire fighting equipment and systems are checked. This group also contains the testing of the emergency fire pump which is not always performed but can be a detainable item if not working.

Figure 40: Contribution Weight towards Detention: General Cargo



Ship and cargo operations are a combination of SOLAS and MARPOL operational related deficiencies where items such as the 15 ppm Alarm (oil water separator), the oil record book, SOPEP[85] and garbage management as well as fire and abandon ship drills can be found. In addition, for tankers this group of deficiencies can be more important due to the more complex cargo operations on chemical tankers, gas carriers and oil tankers. This group of codes is expected to show higher percentages for the USCG since ships have to perform fire and safety drills during inspections. Failure to comply with the drills to the satisfaction of the inspector will show up under this code as well as under the ISM (Management) code.

What is interesting to notice is the relative high contribution of *ISM (Management)* related deficiencies for some ship types and regimes. As mentioned previously, this group of codes represents the safety management system while the group of codes within ship and cargo operations and safety & fire appliances represents the actual implementation in daily shipboard operations. One regime might put more emphasis on the actual implementation while others will check both aspects. If many deficiencies are found which show a lack of maintenance and/or a lack of the implementation of operations onboard, it will also be reflected in this group of deficiencies. The difference in this group across the regimes also reflects the philosophy in inspecting and recording ISM related deficiencies.

[85] Ship Oil Pollution Emergency Plan

Figure 41: Contribution Weight towards Detention: Dry Bulk

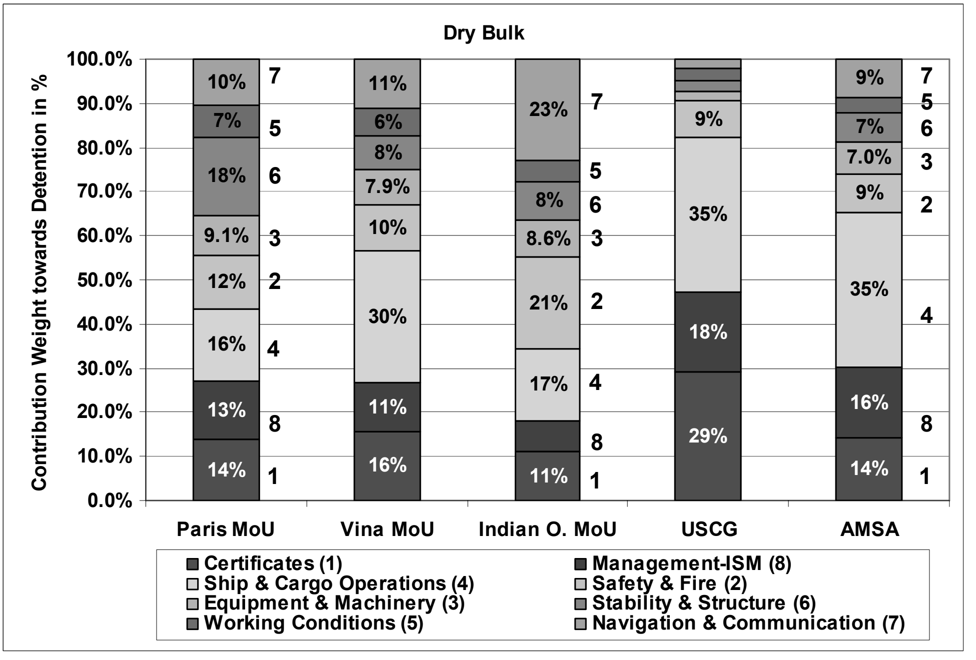


Figure 42: Contribution Weight towards Detention: Tanker

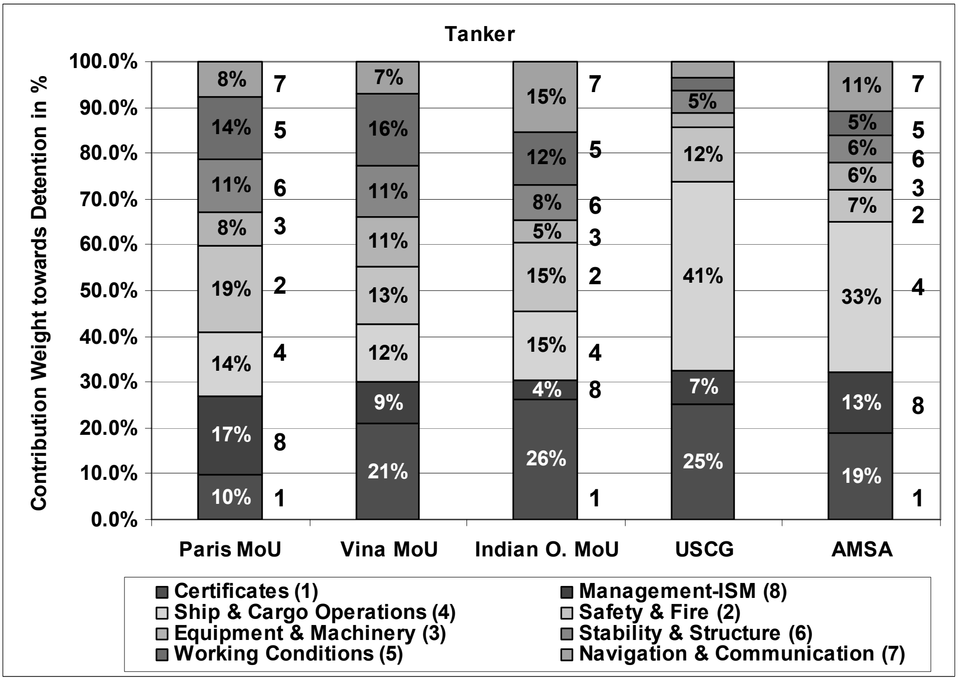


Figure 43: Contribution Weight towards Detention: Container

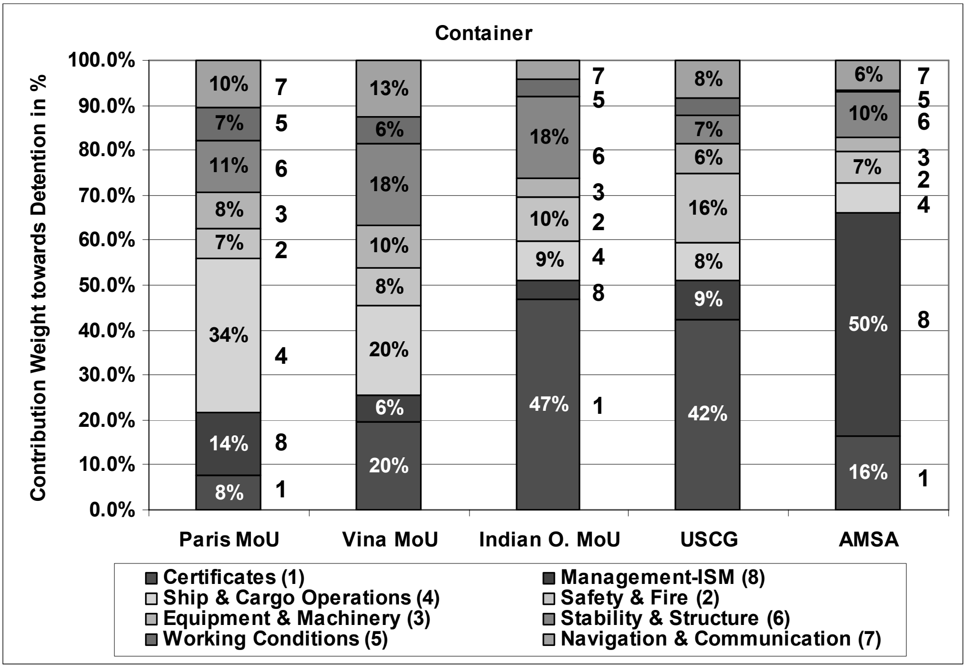
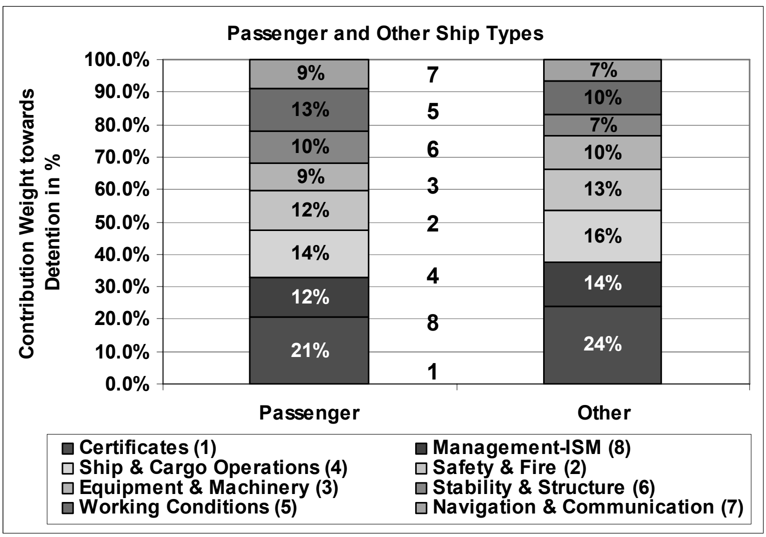


Figure 44: Contribution Weight towards Detention: Passenger and Other Ship Types



The relative low weight percentage for the deficiencies within *stability & structure* is also not surprising since it includes such items as ballast water tank or cargo holds inspections which is difficult to be performed during normal cargo operations. Some regimes might have a different policy with reference to entering enclosed spaces during an inspection. This group of deficiencies only shows a higher contribution for dry bulk and container vessels.

The deficiency groups dealing with *working and living conditions* which is a group of codes related to the ILO varies across the ship types and regimes. The same applies for the group of codes for *navigation and communication*. For passenger vessels and tankers, the first group shows a higher contribution compared to container vessels and dry bulk vessels while for the second group, dry bulk and general cargo seems to perform worst with respect to navigational items. Also these two groups of codes vary the most across the regimes which indicates the different ship profiles as well as the different emphasis that is given during an inspection.

The lowest contribution for all ship types and regimes can be found for *equipment and machinery* which is also not surprisingly. The engine room and its machinery is normally part of an inspection round but is not core emphasis of a port state control inspection.

3.3.9. Differences in Port States

This section will look at the probability of detention showing the differences based on selected ports for several regimes for the five major ship types. Not all cargo types are handled in each port or port state. The same ship profile was used for all ship types with the exception of tonnage and is as follows where the result can be seen in Figure 45.

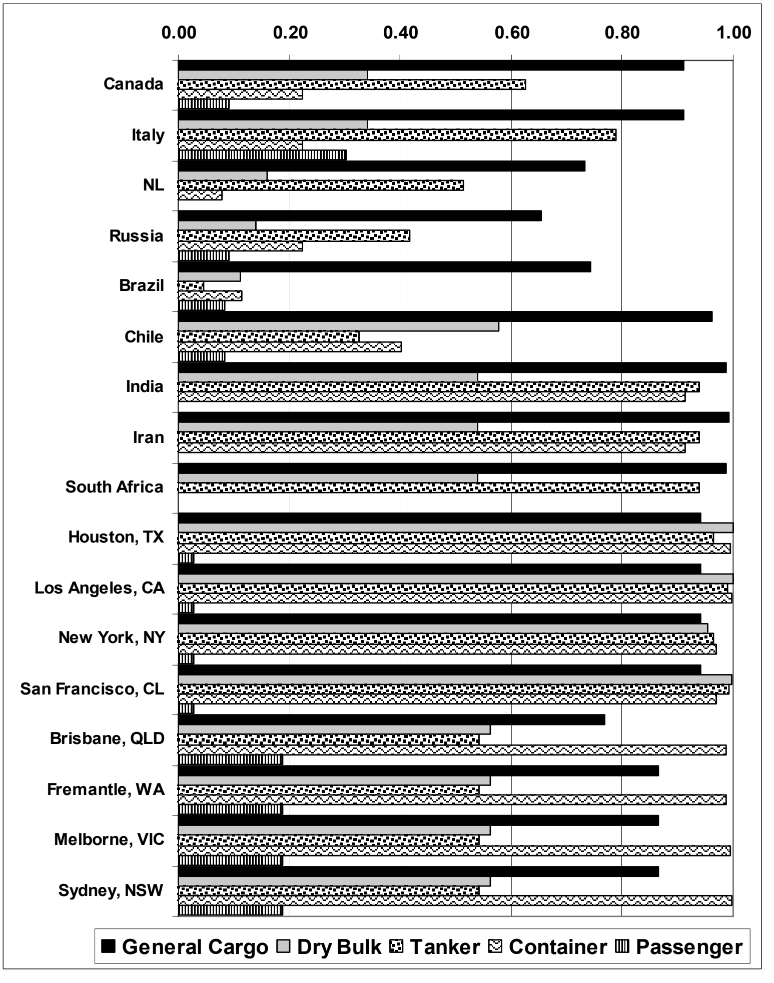
The ship profile used in the graph is as follows:

1. Age: 13 years
2. Gross Tonnage: from 5,900 gt (general cargo), 38,995 gt (dry bulk), 27,322 gt (container), 28,909 gt (tanker and passenger)
3. Class: Det Norske Veritas
4. Flag: Panama
5. Owner: Traditional Maritime Nation
6. Deficiencies: certificates (1), safety & fire appliances (3), ISM code (1), equipment & machinery (1)

General cargo ships tend to have the highest probability of detention across all regimes with the exception of AMSA. The other ship types vary. The USCG shows higher probabilities for all ship types with the exception of the passenger vessel. The probability of detention does not vary much from port to port for both the USCG and AMSA while it can vary for the other regimes. This is understandable since it compares countries with a group of several countries. This shows that there is room for harmonization of inspections across the countries of the regimes as well as across the regimes.

It further shows that the worst performing ship type is the general cargo ship which is not surprisingly since it is also a ship type which is not inspected by any of the vetting inspection systems. The probability of detention of the ship type tanker varies the most across regimes followed by dry bulk carriers. Tankers are extensively inspected by the vetting inspection companies but depending on the deficiency found, might easily be detained due to the potential high risk impact, an oil tanker or chemical tanker could have if it is found to be sub-standard. The same should technically apply to passenger vessels but in this category, political considerations might also play a rule and ships are less likely to be detained.

Figure 45: Probability of Detention and Selected Port States

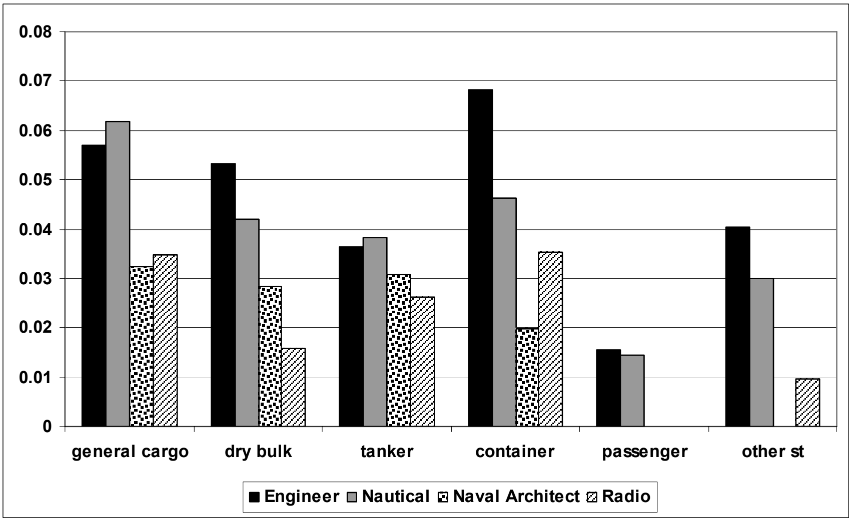


3.3.10. Average Probabilities based on Inspector's Background

The next series of graphs gives an insight into the probability of detention given the port state control's inspector previous background. This information was only available for one of the regimes and is therefore only based on this particular regime. The requirements of becoming a port state control officer varies across the regimes but most regimes with the exception of the USCG require previous sea going experience or a background as a naval architect. Figure 46 shows the average probability of detention per ship type and the inspector's background while Figure 47 gives the breakdown per deficiency category. It is based on 16,773 inspections from the time period 1999 to 2004 where 682 records are unknown and therefore left out of the total data to be drawn from.

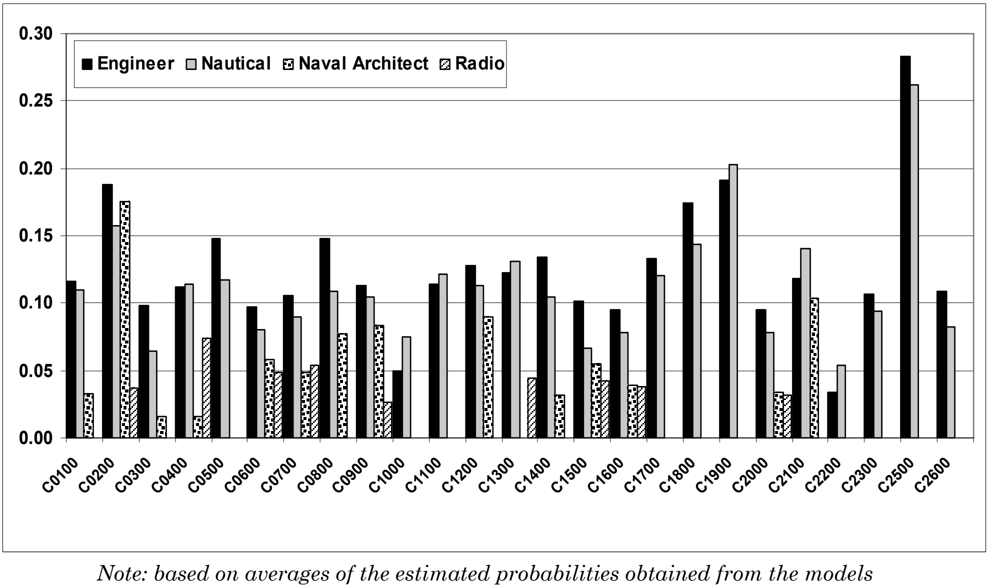
The graphs show that the average probability of detention varies amongst the different backgrounds of the port state control officers with respect to ship types where the largest difference is around 5% on container vessels between inspectors with an engineering background versus a naval architect background. Looking at the deficiency codes itself, one can notice that most of the time the probability of detention of inspectors with an engineering background seems to be slightly higher compared to a nautical background. For the other two groups, the results are to be interpreted with caution since not much data is available for these two groups.

Figure 46: Average Probability of Detention per Inspector's Background



Note: based on averages of the estimated probabilities obtained from the models

Figure 47: Average Probability of Detention per Inspector's Background



Note: based on averages of the estimated probabilities obtained from the models

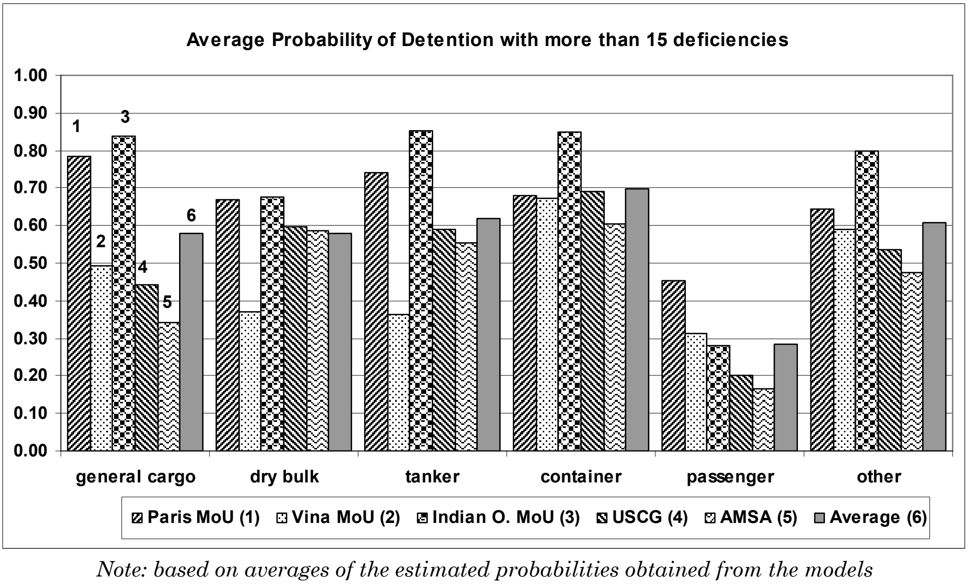
The two main groups are inspectors with either a nautical background or an engineering background. The difference between these two groups can be up to 4% for code 800 (Accident prevention) but most of the time lies between 1 to 3%. What is interesting to observe is that inspectors with engineering background do not necessarily show a lower probability in deck related deficiencies such as code 1500 (safety of navigation) or 1600 (radio communications) while it does show a difference in code 1400 (propulsion and aux. machinery) in comparison to inspectors with a nautical background.

This analysis can conclude that there are differences which are expected to exist but that this type of analysis would require further insight and better underlying data collection for the other two groups (naval architect and radio) in order to make a final conclusion on the subject in question. It is a first insight into trying to explain the differences in the probability of detention and the use of the deficiency codes towards it.

3.3.11. Overall View Based on Average Probabilities

The final section will provide an overall view of the probability of detention based on all ships in the total inspection dataset with more than 15 deficiencies and with no deficiencies and their estimated average probabilities. The results are based on 5,212 ships and 98,953 ships respectively and are shown in Figure 48 and Figure 49.

Figure 48: Probability of Detention per Ship Type (> 15 deficiencies, 5,212 ships)

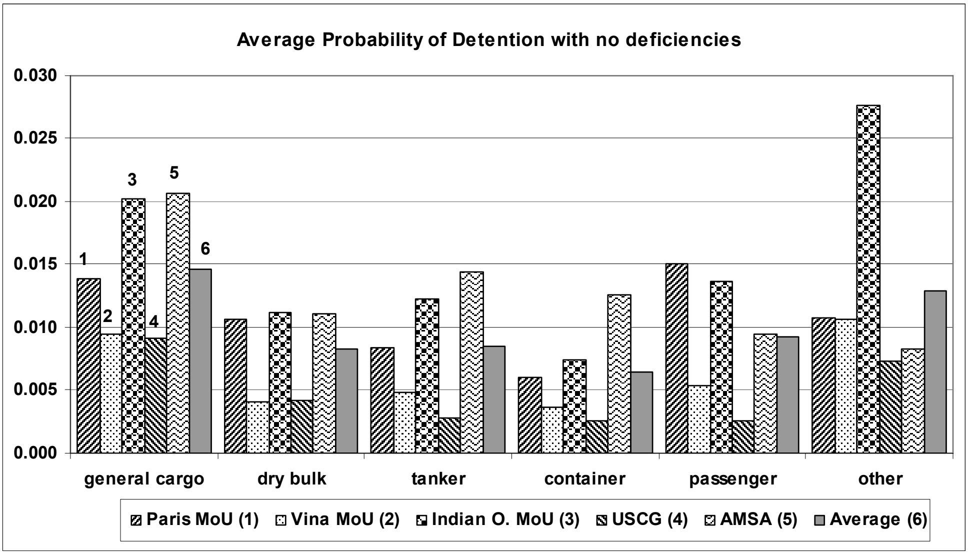


Note: based on averages of the estimated probabilities obtained from the models

The difference across the regimes is primarily based on the contribution of the deficiency codes and the port states. While some differences can be found in flag and class, age and vessel size are not the major factors contributing the difference as could be seen when testing the coefficients for restrictions in section 3.3.3. Step 2 Results: Coefficient Testing (Performed in 2 Rounds).

The graphs should not be used as a measurement of the quality of the inspections. It shows the differences with respect to detention in mainly the deficiency codes as well as the port states. The results for passenger vessels and other ship types are a less accurate measurement due to the fact that only one model per ship types could be formed and not for each MoU. It therefore cannot distinguish the differences based on class, flag, age, size and deficiencies across the MoU's but only gives an overview of the differences based on the port states and a variable indicating the regime (e.g. passenger vessel coming into MoU 1).

Figure 49: Probability of Detention per Ship Type (No deficiencies, 98,953 ships)



Note: based on averages of the estimated probabilities obtained from the models

The basic probability based on zero deficiencies can be understood as the portion of the probability based on the ship profile and lies between 0.5% and 1.5% for most ship types and regimes. This is also the portion that will be related to the probability of casualty in the next part of the thesis to compare with the probability of casualty. Only other ship types for the Indian Ocean MoU shows a higher percentage. The picture then changes when looking at ships with more than 15 deficiencies where the average probability increases accordingly due to the factor associated with the deficiencies.

3.4. Summary of Major Findings: Port State Control

About half of the world fleet (47%) is subject to port state control. Out of these 47%, most ships inspected are general cargo ships (36%) followed by dry bulk (26%), tankers (19%), containers (10%) and passenger vessels and other ship types. Out of the total inspections, 53.8% are inspections without deficiencies and 5% end up in a detention while aggregated by ship, the 53.8% decreases to 16.3% and detention increases from 5.44% to 24.6% of all inspected vessels for the time frame 1999 to 2004. 66% of the ships detained (1999 to 2004) have been detained once and 6% have been detained four or more times. The average amount of inspection frequency lies by 7 over the time period 1999 to 2004. This amount might be higher in reality since data from some regimes could not be obtained and not the whole time frame can be covered by all regimes who did supply data. Around

68% of the ships with deficiencies have 1 to 5 deficiencies and 6% show more than 15 deficiencies.

The basic ship profiles given by age, size, flag, class and ownership do not vary significantly across the regimes with respect to the probability of detention. Most differences across the regimes can be found within the use of deficiencies towards detention and the port states. When aggregated by ship types, the differences average out but looking at the ship types individually, one can see that certain codes show higher contributions compared to each other within each of the regimes. The basic ship risk profile for all regimes is between probabilities of detention of 0.5% to 1.5%.

Highest contribution can be found for the deficiency groups' certificates, ship and cargo operations, the ISM code and safety & fire appliances while lowest contribution is found for machinery and equipment. Ship and cargo operations seem to be more important for tankers while stability and structure are highest for dry bulk carriers and containers.

What is interesting to notice is the relatively high contribution of ISM (Management) related deficiencies for some ship types and regimes. This group of codes represents the safety management system while the group of codes within ship and cargo operations and safety & fire appliances represents the actual implementation in daily shipboard operations. One regime might put more emphasis on the actual implementation while others will check both aspects. The deficiency groups working conditions and navigation and communication show the highest variation across the regimes.

The difference between the probabilities of detention given a certain background of an inspector is reflected for certain deficiency codes but not necessarily as one would expect intuitively. For inspectors with nautical background versus engineer background, the differences in the probability of detention can be up to 4% for code 800 (Accident prevention) but most of the time lies between 1 to 3%. What is interesting to observe is that inspectors with engineering background do not necessarily show a lower probability in deck related deficiencies such as code 1500 (safety of navigation) or 1600 (radio communications) while it does show a difference in code 1400 (propulsion and aux. machinery) in comparison to inspectors with a nautical background.

This chapter provides a method to calculate the estimated probability of detention which will be linked to the next chapter which will provide the estimated probability of casualty in order to see if the correct ships are targeted for inspection or if targeting can be improved. Contrary to industry knowledge, this analysis does not necessarily confirm that the performance of flag or class varies significantly across the regimes. What it does confirm is that the differences across the regimes seem to be influenced by the port states as well as the use of the deficiency codes towards detention.

PART III

This part of the thesis consists of three chapters and will link the inspection datasets to the casualty dataset and try to find the answer to the main research questions which are as follows:

1. What is the overall effect of inspections on casualties?
2. Are the correct ships targeted for inspections and can targeting be improved?
3. Can inspections be further enhanced?

The part starts with a short explanation on the selection of port state relevant casualties and the respective datasets used for the different regressions. It will link the probability of detention obtained in part II to the probability of casualty.

The regressions are performed on two datasets. First, an analysis is performed on the casualty dataset itself and second on a matched dataset of inspection ships with casualties versus inspected ships without casualties.

Chapter 5: Key Statistics on Casualties and Overview of Datasets

This chapter will first give an overview of the selection of the casualties used for the regressions as well as explain the datasets that are used. It will further give some key descriptive statistics on casualties with reference to ship particulars, casualty severity and locations.

5.1. 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[86]
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.

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 and already listed in detail in Chapter 3 of this thesis:[87]

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 which are used for the regression analysis in the last section of this thesis. The casualty first events are classified as follows:

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[86] 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.

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

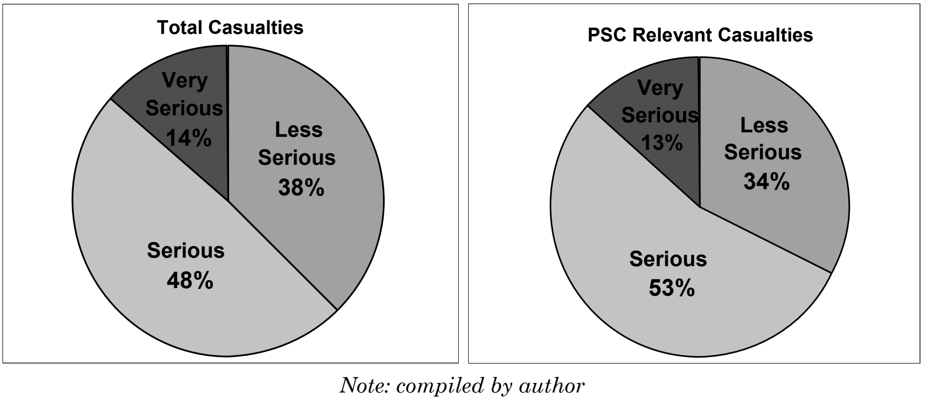
- *Deck and Hull related casualties:* Deck and hull related items such as maintenance items (cracks, holes, fractures, hatch cover problems, cargo equipment failure, lifeboat gear failure, anchor and mooring ropes problems), stability related items such as capsizing, listing, cargo shifts and flooding
- *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

The next section will give a short overview of some key descriptive statistics with reference to the seriousness of casualty, ship types, locations and the casualty first events.

5.2. Key Descriptive Statistics for Casualties

Based on the definitions of the seriousness of a casualty used by IMO and the selection of port state control relevant casualties as explained earlier, Figure 50 gives an overview of the split up of the seriousness of casualties. The percentage of serious casualties and less serious casualties changes when comparing total casualties to port state control relevant casualties only. Although all three categories are taken into consideration in the regressions in the two following chapters to come, very serious and serious casualties are to be understood to be more relevant for port state control than less serious casualties.

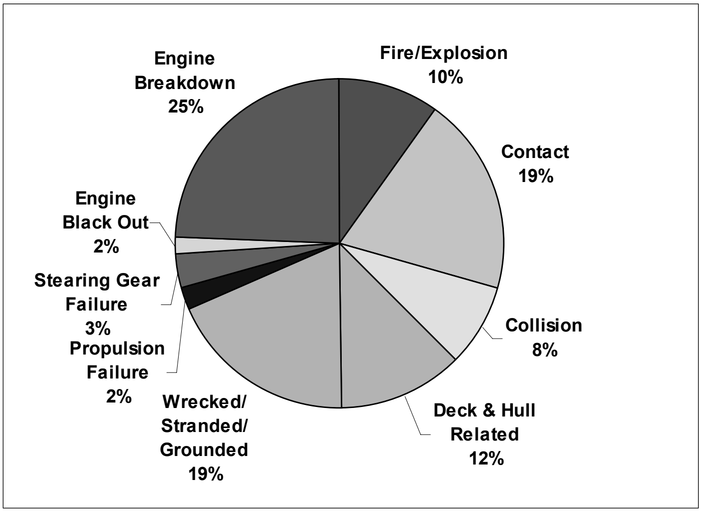
Figure 50: Seriousness of Casualties (1999 to 2004)



Note: compiled by author

Figure 51 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. What is 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).

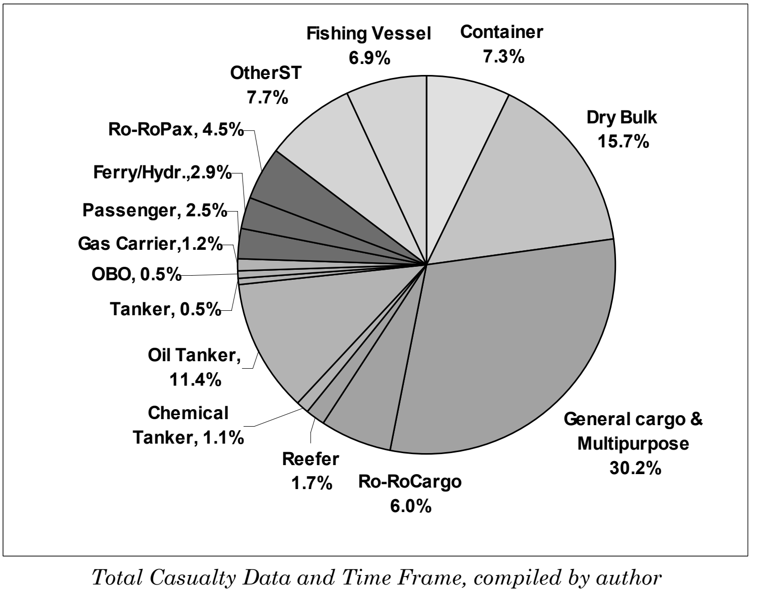
Figure 51: Casualty First Events per Ship Type (1999 to 2004)



PSC Relevant Cases, compiled by author

Looking at the casualties per ship type for the whole time period (1993 to 2004) as can bee seen in Figure 52, most casualties can be found with general cargo and multipurpose ships and dry bulk carriers.

Figure 52: Ship Types and Casualties (1993 to 2004)

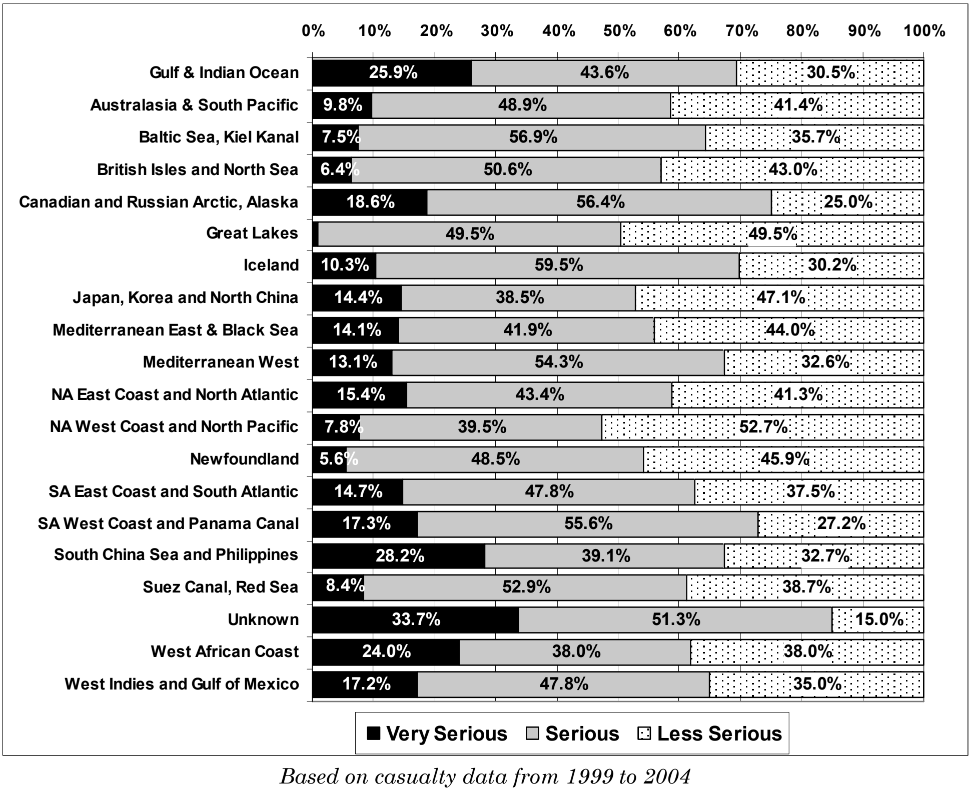


Total Casualty Data and Time Frame, compiled by author

What is interesting to see in the graph is that the casualties on fishing vessels account for 7% of the total casualties of the total dataset but are primarily not part of the port state control system. Very few fishing factory vessels which are technically not fishing vessels (0.3%) are inspected by the port state control regimes. In the casualty regression analysis, the fishing fleet is treated separately and only fishing vessels above 400gt are taken into account.

Figure 53 gives the split up per seriousness and Figure 54 by pollution type and region. The regions with the highest percentage of very serious casualties are the Gulf & the Indian Ocean, the South China Sea, the Philippines and the West African coast. For serious casualties, regions with above 50% are the British Isles and North Sea, the Baltic Sea, the Canadian and Russian Arctic, Iceland, the Mediterranean West, the South Atlantic US West Coast and Panama Canal. A certain percentage of cases were unknown where about 50% are allocated to serious casualties, 33% to very serious and the rest to less serious casualties.

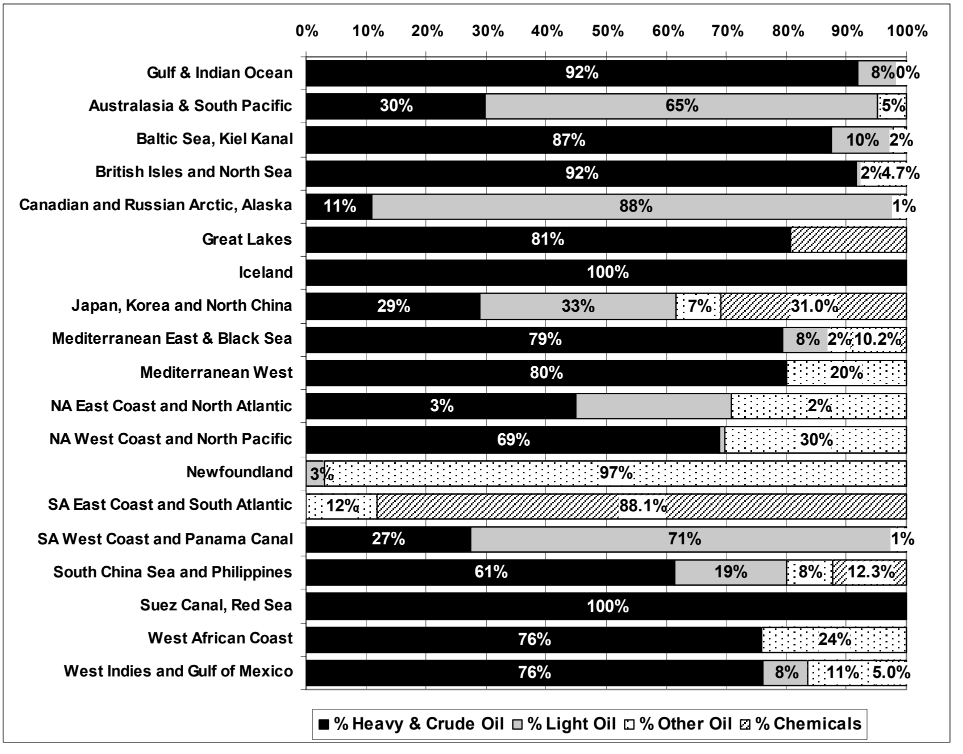
Figure 53: Seriousness of Casualty per Region (1999 to 2004)



Based on casualty data from 1999 to 2004

As for the split up of the type of pollution, the details can be seen in the graph below which gives a detailed view of the type of pollution per area. Most pollution for the time period 1999 to 2004 originated from heavy and crude oil followed by chemicals, light oils and any other oils which are mainly oily waters. The split up varies considerably per region.

Figure 54: Pollution Type per Region (1999 to 2004)



Based on casualty data from 1999 to 2004

5.3. Overview of Inspections and Casualties

The last section in this chapter should give an overview of the PSC eligible fleet in relation to port state control inspections and casualties which is shown in Figure 55. The fishing vessels (>400gt) of which the casualties are also considered in the regressions are also incorporated into this figure.

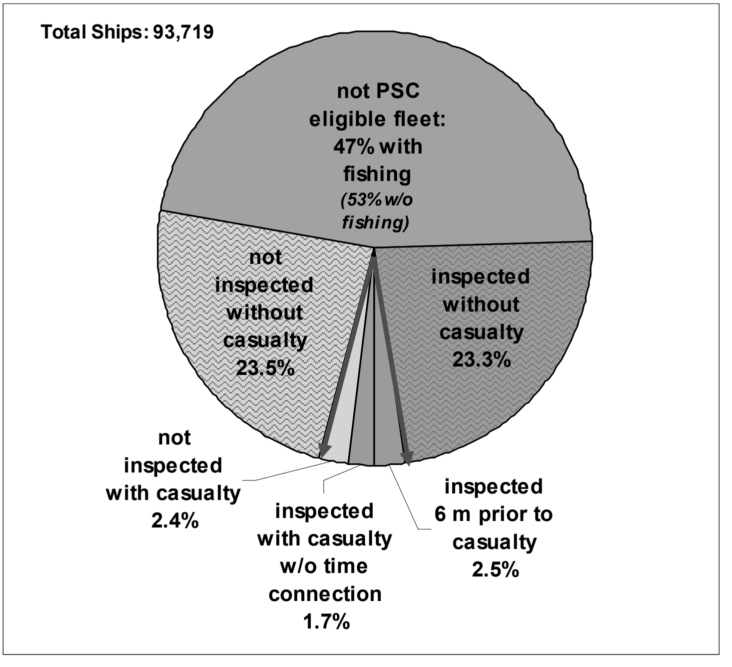
The graph gives an overview of the total fleet where the portion on top shows the portion not exposed to port state control minus a portion of the fishing fleet (above 400gt) which is also considered in this study. The right hand lower part of the graph represents inspected ships and the left hand side of the graph represents ships that have not been inspected by the respective regimes[88] or not inspected at all. The lower middle portion summarizes the vessels that had casualties.

One can see that about an equal amount of ships that had not been inspected by the regimes in question (they might have been inspected by another regime only) did not have a casualty – about 46% (23.5% plus 23.3%) of the world fleet including fishing vessels

[88] As explained previously, some Port State Control regimes decided not to participate in this study such as the Tokyo MoU, the Black Sea MoU or the Mediterranean MoU while others did not have any data available yet.

above 400gt. Not inspected ships with casualties accounted for 2.4% of the world fleet versus 1.7% of the vessels which had a casualty and were inspected without any related time frame and 2.5% of the vessels were inspected six months prior to a casualty.

Figure 55: The Overall View on Inspections and Casualties (1999 to 2004)



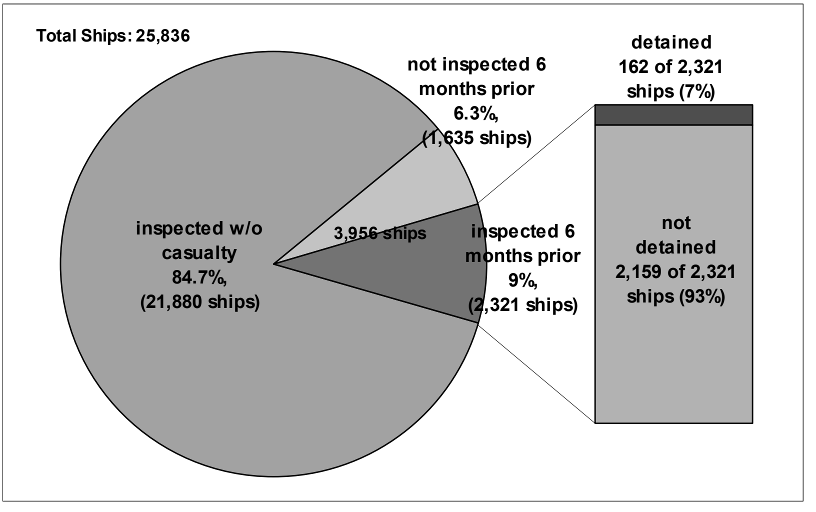
Note: Casualties are over a time frame (1999 to 2004) and only PSC relevant casualties are shown in this graph plus the fishing fleet (>400gt)

What is interesting to notice but which is not shown in this graph is that, based on the individual port state control inspections, 54% of all inspections were inspections with zero deficiencies while when aggregated by ship and taken as a summary of all inspections performed on vessels, this percentage reduces to 16% of all inspections for the time frame 1999 to 2004. On the other hand, if only looking at the last inspection six months prior to a casualty as shown in the figure with 2.5% of the total world fleet, 52.3% of these vessels were ships with zero deficiencies. The lower left side of Figure 55 then shows the portion of ships that have not been inspected but had a casualty which accounts for 2.4% of the vessels. In number of ships, this accounts for 2,213 vessels or approx. 369 ships per year. This could indicate a possible room for improvement of targeting vessels.

Zooming into inspected ships only, the result can be seen in Figure 56. From a total of 25,836 ships with inspections, 3,956 ships had a casualty and 2,321 ships were inspected within a time frame of six months prior to a casualty. Of these 2,321 ships, 162 were detained which accounts for 0.6% of total inspected vessels (25,836), 4% of vessels with casualty (3956 ships) or 7% of ships with casualty and inspection six months prior to casualty.

It is interesting to see that the percentage of very serious and serious casualties is higher for vessels that have been inspected and detained six month prior to the casualty then for vessels that have not been detained. The effect of detention will be closer looked at in Chapter 7 of this thesis but Figure 57 gives a further split up of the seriousness of the casualties and detention. Detained ships show a considerable higher amount of very serious and casualties then not detained ships.

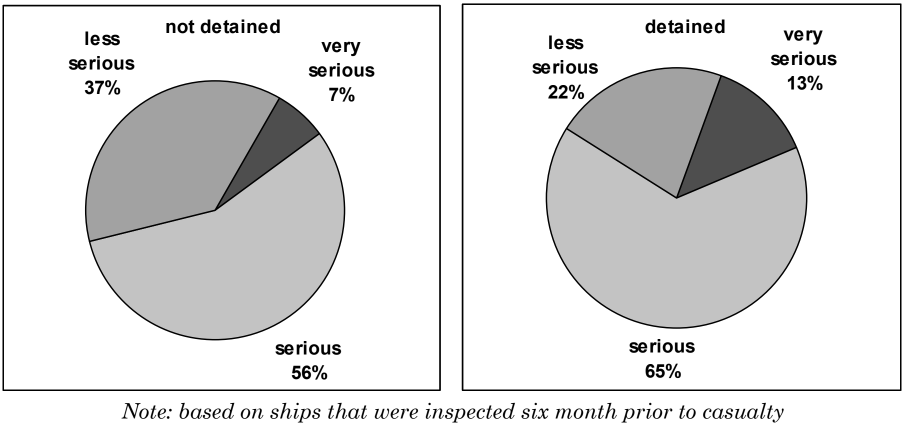
Figure 56: Ships Inspected in Relation to Ships with Casualties (1999-2004)



Note: compiled by author

Room for improvement to target vessels can be identified in the area of vessels that had a casualty but were not inspected and in the portion of vessels that were inspected but without any time related to the casualty. Another area of improvement for the inspections itself versus the targeting could be within the portion of ships that was inspected and/or detained six months prior to a casualty.

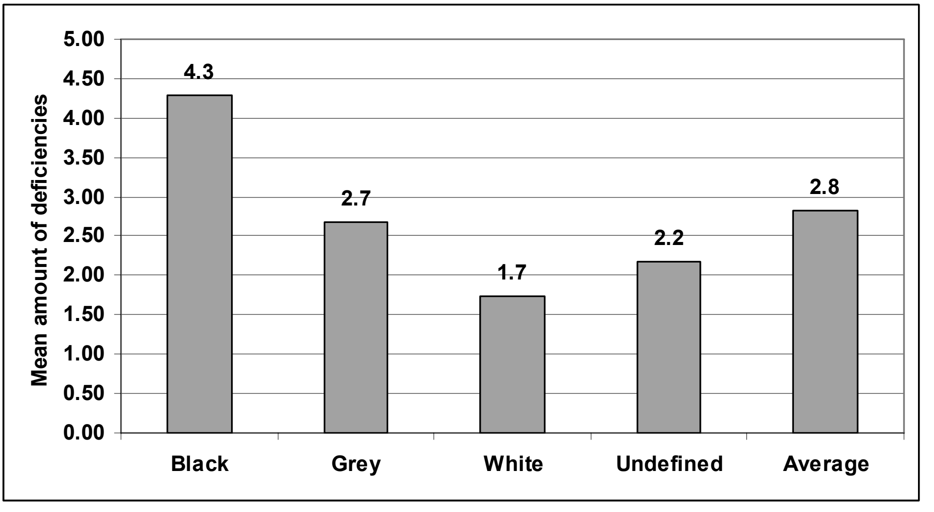
Figure 57: Ships Detention and Seriousness of Casualty (1999-2004)



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

Figure 58 gives an overview of the mean amount of deficiencies found six month prior to a casualty per flag state group while Figure 59 shows the split up for IACS recognized classification societies and non IACS recognized classification societies. 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.

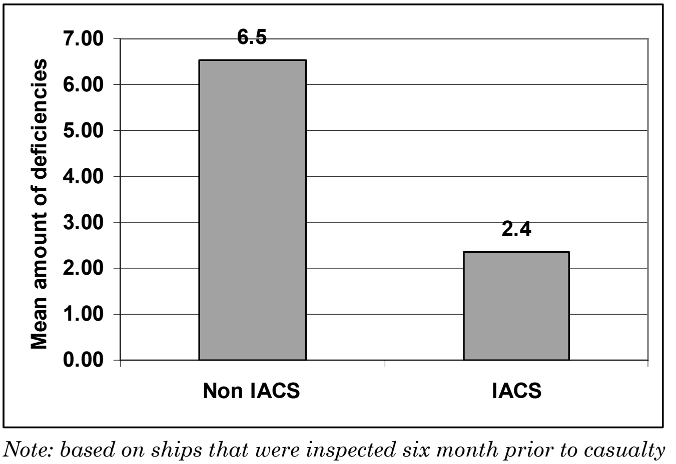
Figure 58: Mean Amount of Deficiencies per Flag State: 6 months prior to casualty



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

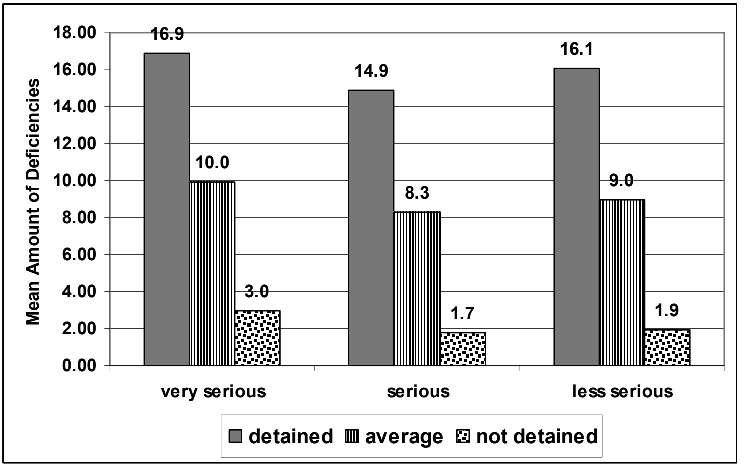
Figure 60 shows the mean amount of deficiencies that are found previous to a casualty per seriousness of casualty and detention. Ships that have been detained show a significant higher amount of deficiencies than ships that have not been detained prior to a casualty.

Figure 59: Mean Amount of Deficiencies per Class: 6 months prior to casualty



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

Figure 60: Mean Amount of Deficiencies per Seriousness of Casualty

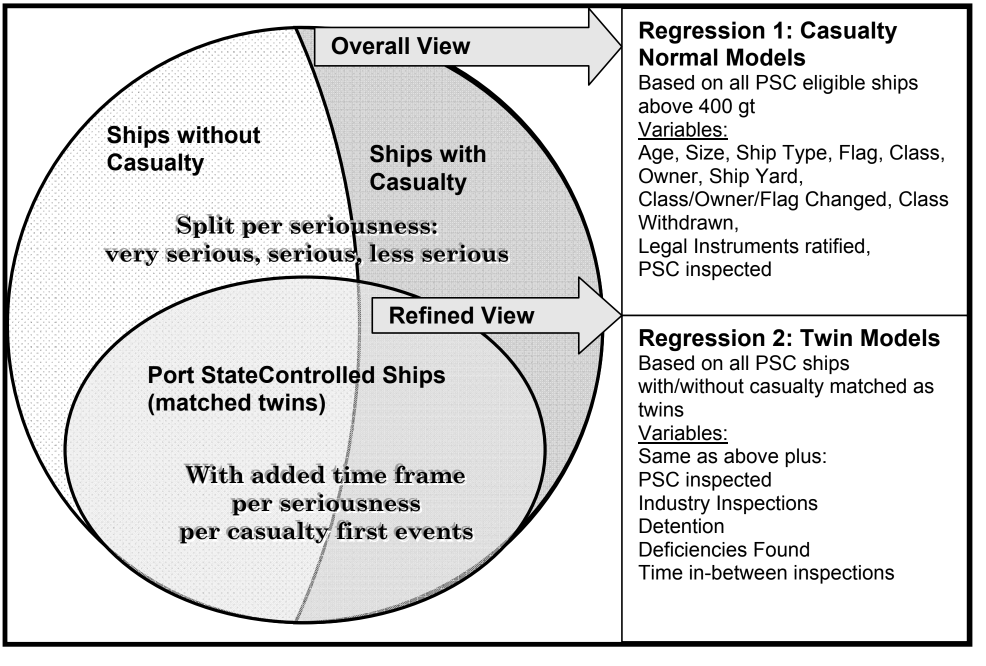


Note: based on ships that were inspected six month prior to casualty

5.4. Overview of Dataset Combinations for Regressions

This chapter will give an overview of the selection of datasets for the two types of casualty regressions that are used in the two chapters that will follow. Figure 61 shows the combination of datasets that were used.

Figure 61: Description of Dataset Combinations for Casualty Regressions



The first type of regressions (Chapter 6) is based on the total dataset of PSC relevant casualties and all ships with no casualties in the time frame 1999 to 2004. Therefore, it is based on the total world fleet. This type of regression should give an insight of the overall effect of inspections in comparison to ships that were not inspected by the respective regimes. It also gives some insight into the target factor to see if the correct ships are chosen for inspections by comparing the probability of detention provided by Part II of this thesis with the probability of casualty.

The second type of regression (Chapter 7) then only takes port state controlled ships into account and compares ships that had a casualty with a ship that did not have a casualty. For the ships with casualties, twins are matched according to certain criteria which will be explained in detail in the respective chapter of the model itself.

The reason for the matching twins (sister ships) is to refine the comparison and to allow the filtering out of the variables that are of interest in these regressions – the variables that describe the quality of an inspection such as detention, the deficiencies that were found, the regime who inspected the vessel, vetting inspections and the time in-between PSC inspections. This regression further introduces a time frame and only looks at ships with an inspection six months prior to the casualty. In addition, a series of separate regressions based on casualty first events is introduced in order to gain more insight between the deficiencies that are found prior to a casualty and the casualty first events.

It is important to notice that ships appear only once in each of the datasets meaning that if a ship had several casualties, its casualty history is reflected in the record but the ship does not appear several times as a separate observation. The same applies for the inspection history. The numbers reflected in the variables are therefore averages of the ship's total history of inspection and casualties. The only time a ship can re-appear in the datasets that are used for either type of regression is because of the seriousness of a casualty or if it is a multiple twin.

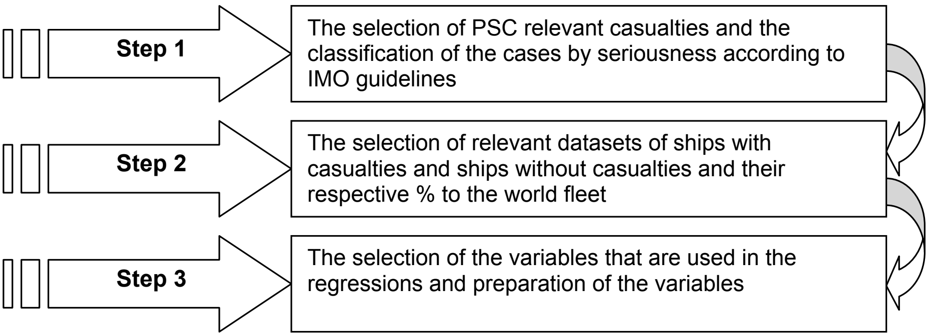
Chapter 6: Probability of Casualty – Overall View

This chapter tries to identify the difference of the probability of having a casualty (very serious, serious, and less serious) between inspected ships and not inspected ships to see what the effect is of inspections on casualties. It further links the findings of the probability of casualty with the probability of detention to see if the correct ships are targeted for inspections. The chapter will first start with an explanation of the dataset that is used for the regression analysis.

6.1. Preparation of Datasets and Sample Sizes

Figure 62 gives an overview of the steps that were performed to prepare the relevant datasets. The *first step* was the selection of casualties and their re-classification according to the IMO guidelines. The *second step* was the selection of the relevant datasets and the *third step* the selection of variables used in the regressions.

Figure 62: Description of Methodology Used



6.1.1. The Selection of Relevant Casualties

The selection of relevant casualties is covered at the beginning of Chapter 5 and is not repeated here. The data used for the regressions to follow is based on 6005 ships (6169 ships including the fishing fleet) with a casualty. The classification of seriousness was also explained previously but is repeated here in summarized form[89] for easier understanding:

- ***Very serious casualties:*** casualties to ships which involve total loss of the ship, loss of life or severe pollution
- ***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.

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[89] as per IMO (MSC Circular 953, 14th December 2000)

- *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”.

6.1.2. The Selection of Relevant Datasets

The *second step* was the construction of the dataset and is based on the total casualty dataset (a combination of three sources), the inspection dataset (a combination of six sources and data from the industry), and the general ship dataset including ship’s particulars and ship history data. Table 24 lists the split up of the total dataset between ships that have been inspected and ships that have not been inspected for the time period in question. The fact that the ships have not been inspected does not necessarily mean that they have not been inspected by any of the other regimes where data could not be obtained such as the Tokyo MoU, the Black Sea MoU, or the Mediterranean MoU. Therefore, the dataset measures ships that have been inspected by the combined PSC dataset with ships that have not been inspected at all or inspected by another regime. This will be taken into consideration when interpreting the results. It is difficult to anticipate how the results would change when repeating the regressions with a full inspection dataset.

Table 24: Split up of Ships with casualties versus non-casualties (1999 to 2004)

Summary	Ships not inspected	Ships inspected	Total Ships	% not inspected	% inspected
Casualties	2213	3956	6169	35.9%	64.1%
No Casualties	22061	21880	43941	50.2%	49.8%
Total	24274	25836	50110		

Note: the table includes the fishing fleet used in a separate regression (ships above 400gt)

The total dataset for casualties is based on 6169 ships with a casualty (6,005 without the fishing fleet) and 43,941 (37,812 without the fishing fleet) ships without casualties where the split up of the ships represent a sample similar to the world fleet for ships above 400gt as can be seen in Table 25 .

Table 25: Split up of Ship Types of Sample versus World Fleet (1999 to 2004)

Ship Type	No Casualty Sum	Casualty Sum	Total	Casualties Sample % to Total	Commercial > 400gt*) Sample % to Total	Commercial > 400gt*) Total Ships World Fleet
General Cargo	12539	2665	15204	43.20%	34.7%	33.0%
Dry Bulk	5684	1017	6701	16.49%	15.3%	14.0%
Container	3571	492	4063	7.98%	9.3%	12.0%
Tanker	10184	1033	11217	16.75%	25.6%	25.0%
Passenger	1241	296	1537	4.80%	3.5%	3.0%
Other Ship Types	4593	502	5095	8.14%	11.6%	13.0%
Total w/o fishing	**37812**	**6005**	**43817**	**n/a**	**100.0%**	**100.0%**
Fishing (>400gt)	6129	164	6293	2.66%	n/a	n/a
Total w. fishing	**43941**	**6169**	**50110**	**100%**		

**) Note: the figures on the last column link up to Figure 21: Ships Eligible for Inspection*

The fishing vessels are not split into seriousness but only one regression is performed on the total cases of fishing vessels above 400gt. The ideal situation would have been to include all fishing vessels of which the majority is under 400 gt but due to lack of data, this could not be done. In total four separate regressions are performed: one for each type of seriousness and a separate for all the cases of the fishing fleet. Multiple casualties were not taken into account. A ship with a casualty can therefore appear in each of the datasets if a ship had multiple combinations of casualties. If a ship had the same type of seriousness of casualty more than once (e.g. 2 serious casualties), the ship is only taken into consideration once. Table 26 gives an overview of the amount of observations in each model.

Table 26: Number of Observations in the End Model

Nr. of Observations	Very Serious	Serious	Less Serious	Fishing Fleet
Total Observations	38076	41009	39929	6289
No Casualties	37354	37811	37811	6129
Casualties	722	3198	2118	160
Remarks	Without Caribbean MoU			

Note: Figures are final figures used in the models and without outliers

One could argue that the number of ships with casualties (the 1's in the regressions) is over-represented in the dataset in comparison to the number of ships without casualties (the 0's) since the casualties are an accumulated figure over a time frame of six years where the ships with no casualties are of the same time period but are not counted six times. This raises the question if increasing the dataset accordingly adds more explanatory power to the regression and if the estimations would be different? This subject was investigated by Cramer, Franses, and Slagter (1999)[90] for various sizes of a reduced dataset of zeros and no significant change was found. Therefore, it is assumed that the difference in the sample sizes does not have a serious effect on the coefficients and that by adding more data on the side of the zeros will not add much explanatory power to the models. The resulting probability represents the probability of having at least one casualty in a six year time period and will be converted to a yearly probability for the visualization part. The next section will explain the selection of variables that are used in the regressions as well as give an explanation of the model itself.

6.2. Selection of Variables and Model Explanation

The binary logistic model was explained in detail in Chapter 4 of this thesis and will not be repeated here. It can be written in the form of Equation 4 where the term $x_i\beta$ can change accordingly to the casualty model and is shown in detail in Equation 5 and its variables are listed in Table 27 for further reference. The choice of the variables is based on experience gained from observing inspections and common knowledge of the shipping industry. The probabilities produced are for any individual ship (i) and the rest of the notation is defined as follows: ℓ represents the variable groups, n_ℓ is the total number of variables within each group of ℓ and k is an index from 1 to n_ℓ.

Equation 4: Probability of Casualty Standard Model

$$P_i = \frac{e^{(x_i\beta)}}{1 + e^{(x_i\beta)}}$$

[90] Cramer, Franses and Slagter, (1999) Econometric Institute Research Report, 9939/A

Four different casualty models are created: very serious, serious, less serious and fishing fleet. For estimation, QML (Huber/White) standard errors and covariance is used which is a standard option in Eviews[91]. The reason for using this option was explained already under Chapter 4 and in an effort to keep the methods similar across the different types of regressions; it was decided to also use QML for all types of regressions.

Equation 5: Definition of term $x_i\beta$ of Casualty Standard Model

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

Table 27: List of Variables Used in Casualty Normal Models

		Variable Type Total Number of Variables		**Total** **n_ℓ**
Variable	**ℓ**	**Casualty (Very Serious, Serious, Less Serious) plus a separate regression for the fishing fleet**	**0/1**	**1**
Ln(AGE)	1	Vessel Age at the time of casualty (or inspection)	C	1
Ln(SIZE)	2	Vessel Size in gross tonnage	C	1
ST	3	Ship Type (including fishing vessels)	D	7
STInd	4	Indicates if ship type changed since construction	D	1
CL	5	Classification Societies at time of casualty (or inspection)	D	42
CLInd	6	Indicates if classification society changed over time	D	1
CLWdr	7	Indicates if classification society withdrew	D	1
FS	8	Flag State at the time of casualty/inspection	D	130
FSInd	9	Indicator if flag changed over time	D	1
OWN	10	Ship Owner Countries	D	6
OWNInd	11	Indicates if ownership was changed over time	D	1
SY	12	Country where ship was primarily built (>100 ships)	D	37
LIOWN	13	Number of legal instruments owner country rectified	C	1
LIFS	14	Number of legal instruments flag state has rectified	C	1
DH	15	Double Hull	D	1
RS	16	Ships inspected by Rightship (Vetting Inspection)	D	5
GR	17	Ship certified by Greenaward	D	1
PSC	18	Indicated total # of inspections per ship per regime (Sum)	C	6
		Total for the whole dataset (split into seriousness)		**244**

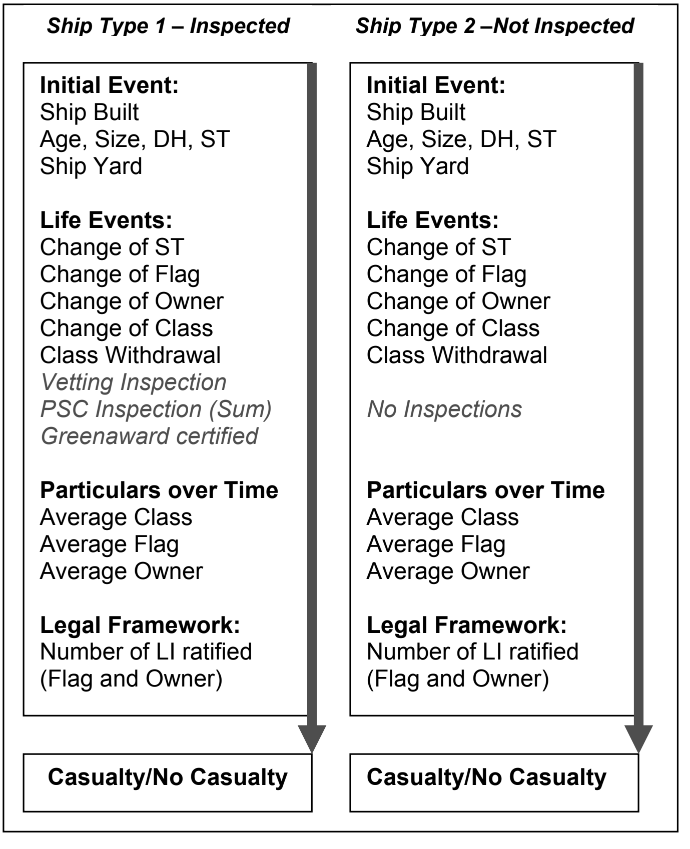
C = continuous, D = dummy of categorical variables

[91] software used to perform the regressions

The variables used in the regressions are similar to the variables used for targeting ships such as age, size, flag, class and owner. The difference to the probability of detention is that it is based on an aggregated ship history versus separate observations.

The variables which indicate change over time such as ship type, class, flag, or ownership are based on information obtained by Lloyd's Register Fairplay and go back in time to either the time the vessel was constructed or at least the last five to six years of the ship being in operation. Three types of inspection variables are introduced. First, a variable which describes if a ship has been inspected by one of the industry vetting inspection systems (Rightship), second, if a ship is certified by Greenaward and third, if a ship has been inspected by one of the respective regimes. Figure 63 shows the variable structure of the two types of ships that are used in this dataset. Ship type 1 reflects ships that have been inspected and ship type 2 are the ships that have not been inspected. Both types can either have a casualty or no casualty as already indicated in Table 26.

Figure 63: Visualization of Variable Structure: Normal Models



6.3. Model Evaluation and Final Results

The model for very serious casualty was tested for presence of heteroscedasticity using the LM test as described by Davidson and McKinnon (1993)[92]. Only the very serious casualty models and the casualty first event models were tested and not the probability of detention models since the author felt that it was more important to investigate heteroscedasticity for the casualty models due to the sensitivity of the topic in question. The probability of detention models only shows the differences across the regimes while the present models use similar variables to show a certain amount of causal relationship. The null hypothesis (H_o) assumes homoscedasticity and the alternative hypothesis assumes heteroscedasticity in the following form where γ is unknown and z are a number of variables which are assumed to be the cause of heteroscedasticity:

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

The test was performed separately for two variables, namely tonnage and age where the test results can be found in the table below and in Appendix 18 for further reference. Presence of heteroscedasticity was found with both variables.

Table 28: LM Test for Tonnage and Age

Variable	LM Statistic	p-value
Tonnage	23.06	0.00000 - *reject* h_o
Age	13.60	0.00022 - *reject* h_o

Note: 1% significant level used

To find out if the presence of heteroscedasticity has an effect on the estimators and the significance of the estimators in the model, a standard program which is part of Eviews (also refer to Appendix 19 for further reference on the adapted version) and which was developed by Greene[93] and based on Harvey (1976) was used. This program allows estimation in the presence of the form of heteroscedasticity defined earlier. The corresponding probabilities are calculated based on Equation 6 where z depicts tonnage alone or tonnage and age and γ the coefficient for tonnage or age obtained by the Greene program.

Equation 6: Probability of Casualty allowing for heteroscedasticity

$$P_i = \frac{e^{\left(\frac{x_i\beta}{\exp(\gamma z)}\right)}}{1 + e^{\left(\frac{x_i\beta}{\exp(\gamma z)}\right)}}$$

The results of the estimation of the model are given in Appendix 19. First, the program was modified for two variables – tonnage and age. In this first trial, age and tonnage were used in z but age comes out not to be significant. Therefore, the procedure was applied a second time without age and the results show that three variables come out not to be significant in comparison to the original model based on Equation 4.

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

[93] 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 the author and for making it available.

To see whether the probabilities differ from the original model and if heteroscedasticity, although present, has a serious effect on the estimation results, the corresponding probabilities are computed for Equation 6 versus Equation 4. The probabilities are then grouped according to tonnage groups, age groups, flag state groups, classification groups and ownership groups and the respective probabilities were calculated based on both models and visualized in Appendix 20. The results further show little difference between the two estimation processes. One can therefore conclude that although some presence of heteroscedasticity is present in the model, it does not have a serious effect on the estimation process with reference to the coefficients and the resulting probabilities and the standard model is used and applied to all models in this section. Table 29 lists the key statistics of the final types of models reduced to 1% significance level for logit and probit estimation and the regression results and be seen in Appendix 21 to Appendix 24 respectively.

In comparing logit with probit, not much difference can be seen in the results other than that the HL-statistic suggests a better fit for the logit model versus the probit model. The results are acceptable for the amount of data in each of the models. The hit rate lies above 74% for all logit models except for the models of the fishing vessels. Outliers were identified and eliminated to improve the fit of the models. The outliers were not analyzed in detail since it was not found that eliminating them will significantly change the results of the regression analysis. This can be left as recommendation for future research. For visualization of the results in the next chapter, the logit model is used.

Table 29: Key Statistics of Final Models: Probability of Casualty

	Very Serious		Serious		Less Serious		Fishing Fleet	
# observations in final model	0 = 1 = Total =	37354 722 38076	0 = 1 = Total =	37811 3198 41009	0 = 1 = Total =	37811 2118 39929	0 = 1 = Total =	6129 160 6289
# of outliers	122		97		35		4	
Cut Off	0.0189		0.0780		0.0530		0.0250	
	LOG	**PRO**	**LOG**	**PRO**	**LOG**	**PRO**	**LOG**	**PRO**
Mc Fadden R2	0.634	0.632	0.281	0.278	0.250	0.224	0.400	0.393
% Hit Rate y=0	93.53	92.60	79.87	78.05	76.09	81.93	89.98	85.51
% Hit Rate y=1	88.64	90.39	74.39	76.92	74.41	68.41	71.25	76.25
% Hit Rate Tot	93.43	92.56	79.44	77.97	76.00	81.21	89.51	85.28
HL-Stat. (df=8)	14.65	48.79	16.92	43.08	17.28	25.93	15.20	19.74
p-value	0.0663	0.0000	0.0309	0.0000	0.0273	0.0011	0.0552	0.0114

6.4. Visualization of Results: Casualty Normal Models

In order to make the interpretation of the results easier, the probabilities are converted from a six year time frame to a yearly probability for the reason explained earlier. The conversion factor is derived as follows.

If p is denoted as a 1 year probability, then the probability of having no casualty in six years equals $1-p$ for 1 year and $(1-p)^6$ for 6 years. The probability of having at least one casualty in 6 years denoted by q is then $1-(1-p)^6$. While q is the result from the models, solving for p leads for the following factor which is then applied to all calculated probabilities in this section to convert the six year probability into a yearly probability:

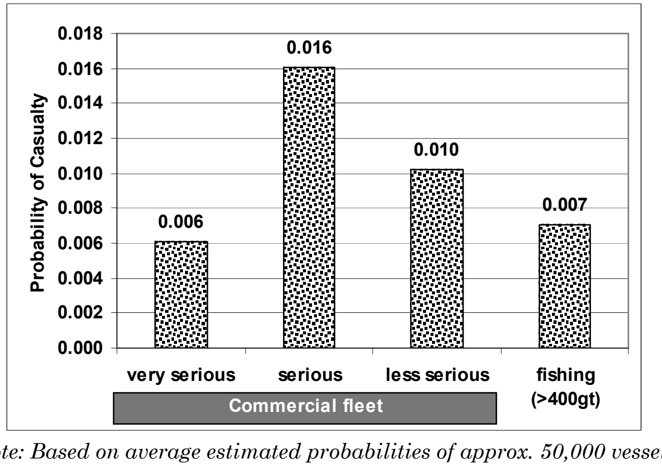
$$p = 1-(1-q)^{1/6}$$

For the purpose of this study, it is assumed that the probability of having at least one casualty in a year is constant across the years which might not completely accurate as this change in probability can be affected by changes the industry such as commercial surroundings. For the purpose of visualization of the effect of inspection on casualties, it is assumed to be accurate enough as the change in probability is not the research question in this study but primarily the effect of inspections on the probability of casualty. The probability of detention is an average probability based on a ship with no deficiencies to reflect the basic ship profile of a vessel in order to bring the two into relation. In order to combine both probabilities, each estimated probability of the total dataset was combined using the IMO number of a respective vessel. For the probability of detention, averages per vessel were taken. The result is a comparison of both probabilities for about 50,110 ships, depending on the size of the actual dataset (e.g. very serious, serious, less serious casualties).

6.4.1. Overall View of Inspected versus Non-Inspected Vessels

Figure 64 shows the average estimated probability of having a casualty based on the total dataset for the commercial fleet (split into seriousness) and the fishing fleet above 400gt. There is no particular reason based on existing legislation for the choice of size with reference to the fishing fleet[94]. The analysis is based on the fishing fleet above 400gt to bring them in line with larger fishing vessels or the so called factory ships. Technically, the factory ships are not fishing vessels and are therefore sometimes inspected by port state control (about 0.3% of the PSC dataset) but they belong to the same industry and are the only ships that can be compared to the larger vessels of the regular fishing vessels. In order to keep the size similar to the commercial fleet, 400 gt were used as cut off point.

Figure 64: Average Probability of Casualty



Note: Based on average estimated probabilities of approx. 50,000 vessels

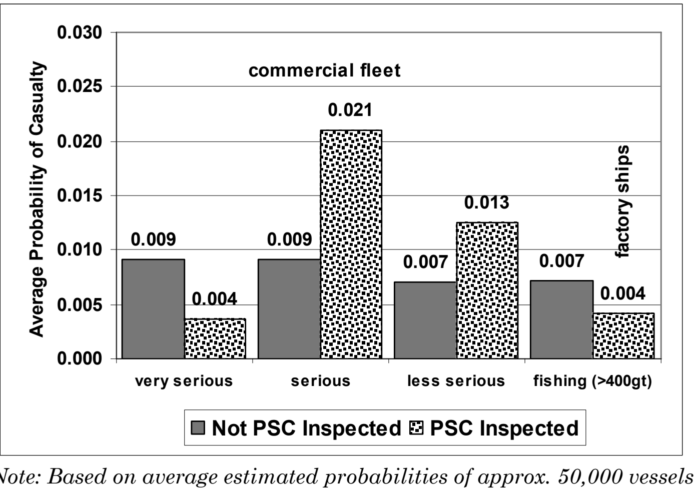
[94] The Torremolinos International Convention for the Safety of Fishing Vessels, 1977 was adopted in 1977 but is not yet in force and only has a provision based on meters and not gross tonnage, http://www.imo.org/home.asp

The basic probability of a very serious casualty lies by 0.6% versus 1.6% for serious and 1% for less serious casualty. The fishing fleet lies slightly above the very serious casualty. In reality, this probability is expected to be much higher for fishing vessels below 400gt but for this analysis, only ships above 400gt are included as explained previously. The next set of graphs shows the difference between the fishing fleet of 400gt and above which is very little inspected by port state control and the commercial fleet. It further shows the main difference between vessels that are inspected by any of the regimes in question versus not inspected by any of the regimes. Not inspected does not necessarily mean that the vessel was not inspected by port state control at all.

Due to the lack of cooperation of some of the port state control regimes, a portion of vessels that are only inspected in these region is missing from the dataset and given the fact that the descriptive statistic section showed that the South and North China Sea are high risk areas with respect to loss of life and collision and contact, there are a portion of ships that fall into the category of non-inspected vessels in this dataset but might have been inspected for instance by the Tokyo MoU. The same applies to a certain extent to the Black Sea MoU and the Mediterranean MoU although the amount of vessels that are inspected by those regimes are also partly covered by the Paris MoU. The results would have been refined by incorporating this data but will be left as a recommendation for future research.

Figure 65 gives an overall picture by comparing the fishing fleet with the rest of the commercial fleet where the probability of casualty is split into type of seriousness for the commercial fleet but not for the fishing fleet.

Figure 65: Probability of Casualty (Inspected versus Non-Inspected Ships)



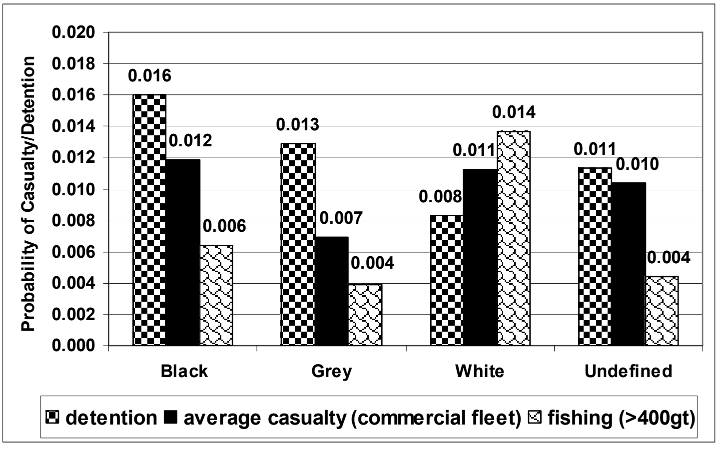
Note: Based on average estimated probabilities of approx. 50,000 vessels

The graph shows that the average probability of a very serious casualty is lower for inspected vessels than not inspected vessels and for the fishing vessels while it is substantially higher for serious and less serious casualties. Overall, it seems to show that ships that are not inspected have a higher probability of a very serious casualty while this is not the case for the other two casualty types. The partial effects on inspection will be shown in the next section and confirm this picture.

The next graph looks into the flag state groupings and also links it with the probability of detention obtained in part II and calculated for a basic ship risk profile without deficiencies on a ship per ship level. It shows that the average probability of casualty is highest for black listed flag states followed by white and grey listed flag states for the commercial fleet while it is highest for the fishing fleet for white listed flag states. This can be explained by the fact that many traditional maritime nations of which their flags are on the white list maintain fishing fleets but these ships are not inspected very often or not at all.

The inspected portions are primarily factory ships. As mentioned earlier, the difference between the commercial shipping fleet and the fishing fleet above 400gt are expected to be much higher if one would include the total fishing fleet. Nevertheless, it shows that inspections have a negative effect on the probability of a very serious casualty as well as for the inspected fishing fleet in general while this effect cannot be seen with serious and less serious casualties for the commercial fleet.

Figure 66: Commercial Fleet versus Fishing Fleet-Flag State Grouping

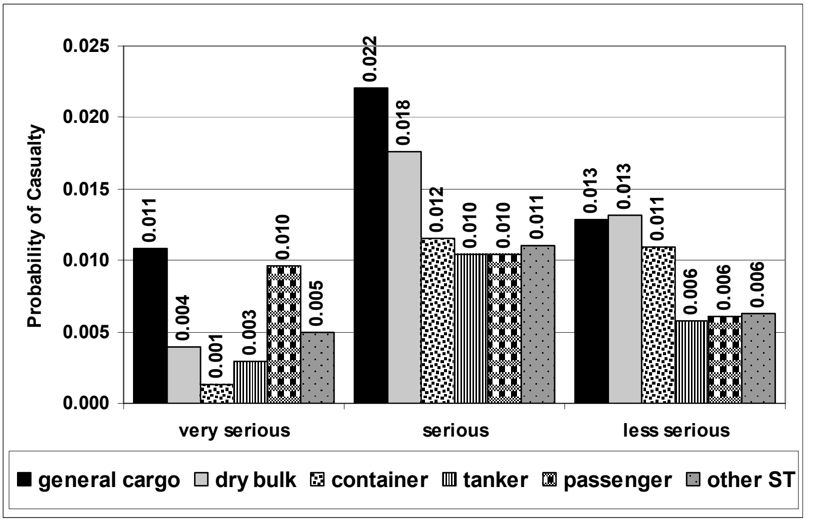


Note: Based on average estimated probabilities of approx. 50,000 vessels, Detention based on ships with zero deficiencies

Figure 67 shows the probability of casualty per ship type. General cargo ships show the highest probability for very serious and serious casualties while tankers and containers show the lowest. It is around 1% for general cargo ships and passenger vessels and 0.1% to 0.3% for container vessels and tankers.

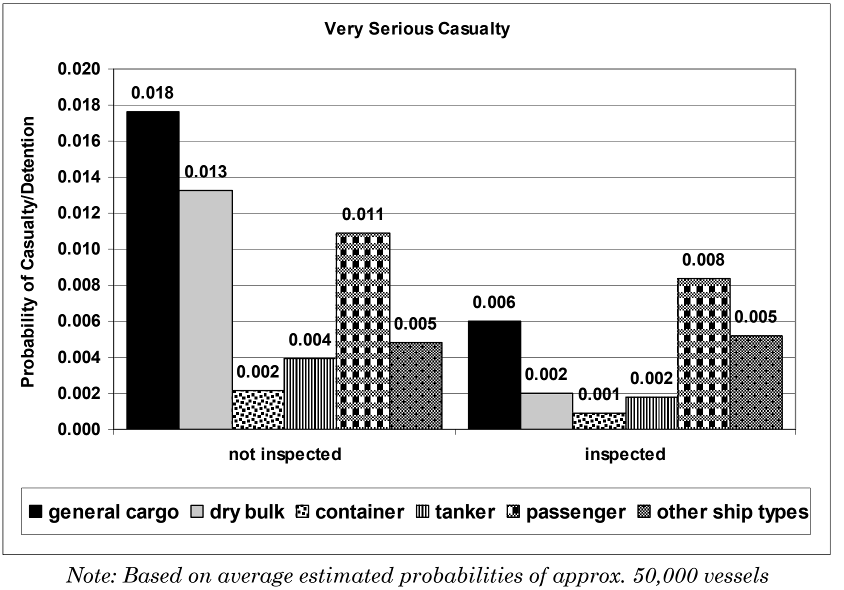
In order to show the difference between inspected and not inspected ships, Figure 68 to Figure 70 provide this information in detail. For very serious casualties, one can clearly see that inspected ships show a lower probability for all ship types. For dry bulk carriers, the difference seems to be the strongest followed by general cargo ships. For tankers and containers, the difference is much less. The smaller difference for tankers can be explained as a combined effect of vetting inspections and port state control while this is not applicable for container vessels. The category passenger vessels comprise mainly Ro-Ro Passenger ships and cruise vessels.

Figure 67: Average Probability of Casualty per Ship Type



Note: Based on average estimated probabilities of approx. 50,000 vessels

Figure 68: Probability of Very Serious Casualty per Ship Type

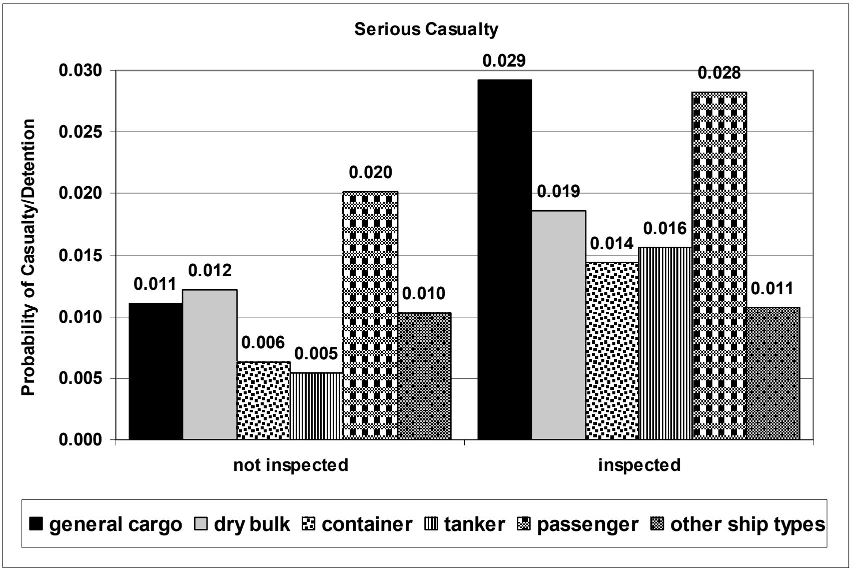


Note: Based on average estimated probabilities of approx. 50,000 vessels

It is difficult to interpret the relative high probability of a very serious casualty for passenger vessels compared to container ships or tankers. This could be due to the fact that a casualty on passenger vessels will most likely include a fatality which would automatically classify as a very serious casualty. In addition, after consulting some experts, the commercial characteristic of operating in the Ro-Ro segment of the industry does not necessarily explain this high probability for European Waters but is more likely to be accepted for other areas where vessels are moved from a stricter area to a less strict area and still continue to operate. Another explanation could be that there are no vetting inspections onboard Ro-Ro passenger vessels as can be found with tankers and dry bulk carriers. Finally, Ro-Ro vessels can carry truck with dangerous cargo and the manifest of the cargo is not known to the crew. Operation is under a tight schedule which can add to fatigue related issues with crew.

Figure 69 and Figure 70 look at the serious and less serious casualties per ship type where the picture changes accordingly. On average, inspected ships show a higher probability of casualty then not inspected ships. It reflects two dimensions. First, the correct ships seem to be targeted for inspection but the partial effect of the inspection variables do not indicate a negative relationship which means that the inspections are less effective or not effective for serious and less serious casualties.

Figure 69: Probability of Serious Casualty per Ship Type

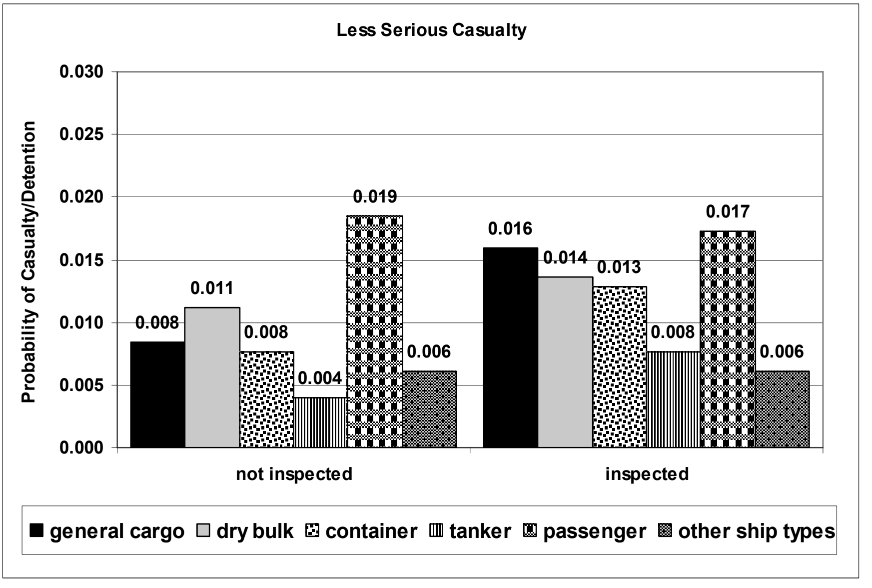


Note: Based on average estimated probabilities of approx. 50,000 vessels

This might be due to the fact that for these two types of casualties, the human element plays a more important role and that therefore, it is more difficult to incorporate this into an inspection. General cargo ships show the highest probability of a serious casualty of almost 3% for inspected vessels and 1% for not inspected vessels. In this category, tankers also show a higher percentage which might indicate that despite the heavily inspected tankers for vetting inspections, the amount of inspections does not have a negative effect on the probability of having a serious casualty but that over-inspection can have an adverse effect on the human factor such as increased stress and fatigue.

In addition, Figure 70 for less serious casualties is more difficult to interpret. Overall, the probability is lower but this might be due to lack of reporting in general. It can be understood as the probability of having a potential serious or very serious casualty which is highest for passenger vessels compared to other ship types. The difference between inspected and non inspected vessels is not very large. The next section will look at the partial effects of inspections on casualties.

Figure 70: Probability of Less Serious Casualty per Ship Type



Note: Based on average estimated probabilities of approx. 50,000 vessels

6.4.2. The Partial Effects of Inspections on Casualties

Table 30 gives a short summary of some of the results of the variables of interest with their respective coefficients and significance across the casualty types. The coefficients are not to be interpreted as direct effects like in linear regression. It is merely the partial effect of a particular variable given all other variables remaining the same.

The interesting part is not necessarily the coefficient but its significance and sign which determines the tendency of the effect towards the probability of casualty. A 1% significance level was used since the author felt that the topic in question is a sensitive issue and therefore, a smaller significance level was felt to be more appropriate. The table summarizes the main findings as follows:

- General cargo vessels seem to show the highest risk although not necessarily the largest costs with respect to the aftermath of for instance pollution deriving from an oil tanker as shown previously in Chapter 2 of this thesis. Second in line are passenger vessels but primarily for serious and less serious casualties.
- Age is only significant for very serious casualties and its effect is positive. A separate graph is shown below to visualize this effect.
- Tonnage is also only significant for very serious casualties but is negative indicating that a smaller vessel seems to be at higher risk than larger vessels which goes in line with the general cargo vessels being more high risk prone.
- The coefficient of the variable indicating if the ship changed its class during its course of life is significant and negative for all types of casualties. This could mean that in general, if a class is changed, an inspection is performed which might have a positive influence on the quality of the vessel. On the other hand, the coefficient of the variable indicating if class was withdrawn certainly shows a positive effect.

- Change of flag does not seem to be significant while change of ownership is significant for all types of casualties but in particular for very serious casualties. The coefficient indicating if an owner changed is further positive. This could indicate that due to the move of a vessel to the second hand ownership market, the money which is normally spent might be less and decrease the overall safety level of a particular vessel.
- The variable double hull is not significant for any type of casualty.
- As for vetting inspections as part of the industry data, the coefficient of this variable clearly indicates that the inspections have a strong negative effect on the probability of a very serious casualty while it is not significant for the other two.
- The last group of coefficients of the variables showing the partial effects of the inspections of a particular regime shows that the effect is negative for all regimes for very serious casualties and varies for serious and less serious casualties. For very serious casualties, the Caribbean MoU had to be excluded due to lack of data.
- Certain classification societies, flag state, ownership variables and ship yards remain to be significant in the models and can be found in the Appendix 21 to Appendix 23 in detail.

Table 30: Summary of Main Variables: Casualty Normal Models

Significance at 1% Variable of Interest		**very serious Coefficient**	**serious Coefficient**	**less serious Coefficient**
Ship Types				
	General Cargo	1.2507	0.6684	0.8451
	Dry Bulk	n/s	0.4078	0.8240
	Container	n/s	n/s	0.7236
	Tanker	n/s	n/s	n/s
	Passenger	n/s	0.5917	0.8217
	Other Ship Types	n/s	n/s	n/s
Ship Particulars				
	Age	0.4059	n/s	n/s
	Tonnage	-0.3717	n/s	n/s
	Class changed	-0.6965	-2.1564	-2.0292
	Class withdrawn	0.5802	0.6703	0.4396
	Flag changed	n/s	n/s	n/s
	Owner changed	5.3686	2.4263	2.1583
	Legal Instr. ratified: Flag	-0.0543	-0.1244	-0.1804
	Legal Instr. ratified: Owner	n/s	-0.0360	n/s
	Double Hull	n/s	n/s	n/s
	Rightship Inspected	-0.9454	n/s	n/s
	Greenaward Certified	n/s	n/s	n/s
Port State Control Inspected				
	Paris MoU	-0.5443	0.0459	0.0535
	Caribbean MoU*)	not in model	n/s	n/s
	Viña del Mar MoU	-0.4934	n/s	n/s
	Indian Ocean MoU	-2.1760	n/s	n/s
	USCG	-1.4685	0.0295	0.0467
	AMSA	-1.5010	-0.1724	-0.1594
Other Variables (indicates number of variables left in model)				
	Classification Societies	1	8	17
	Flag States	4	49	58
	Ownership Groups	4	4	4
	Ship Yard Countries	3	25	26

*Note: n/s = not significant at a 1% level, *) Caribbean MoU is not included in the very serious model due to lack of sufficient amount of data*

The coefficients of the variables indicating where the ship was inspected were tested using the Wald Test for testing restrictions[95] in order to see if the mean varies across the regimes. The null hypothesis (*h_o*) for testing the restrictions states that the means do not vary across the regimes. The results can be seen in Table 31 below for various combinations of variables. For all three types of casualties, two groupings can be found. For very serious casualties, the group containing AMSA, the Indian Ocean MoU and the USCG are similar versus a group containing the Paris MoU and the Viña del Mar MoU. For serious and less serious casualties, the Paris MoU and the USCG are similar but different to AMSA.

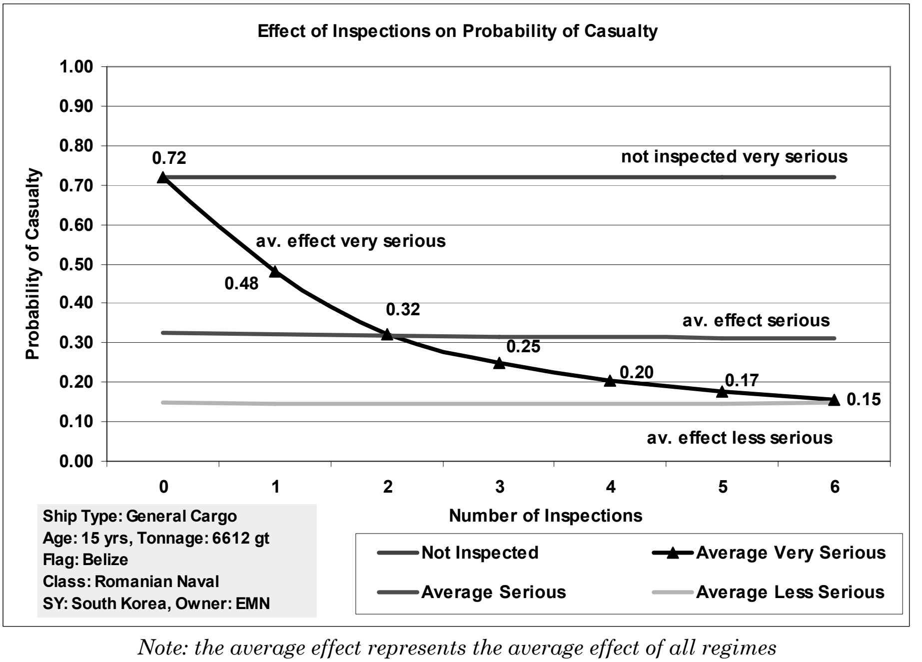
Table 31: Testing of Restrictions - Inspection Variables

Very Serious Restrictions/p-value	Serious Restrictions/p-value	Less Serious Restrictions/p-value
AMSA=IMOU=USCG=PMOU (0.000)- *reject h_o*	AMSA=PMOU=USCG (0.000)- *reject h_o*	AMSA=PMOU=USCG (0.000)- *reject h_o*
AMSA-IMOU-USCG (0.2318)- *do not reject h_o*	PMOU=USCG (0.1526)- *do not reject h_o*	PMOU=USCG (0.6063)- *do not reject h_o*
PMOU=VMOU (0.6845)- *do not reject h_o*	n/a	n/a

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

Figure 71 shows how the probability of casualty changes with the number of inspections of a certain vessel on average. The effect is clearly strongest for very serious casualties and very weak to non-existing or positive for serious and less serious casualties.

Figure 71: Average Effect of Inspection across Regimes on Very Serious Casualties



Note: the average effect represents the average effect of all regimes

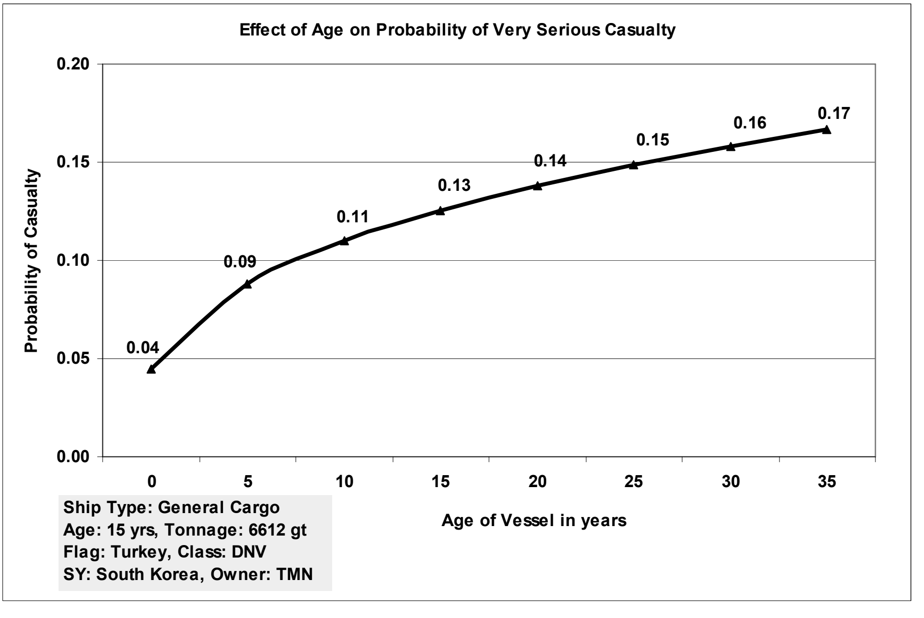
95 based on Wald Test for Testing Coefficient Restrictions, a standard procedure in Eviews

For a vessel having been inspected in one of the regimes, the probability of having a very serious casualty decreases gradually as the number of inspections increases to a maximum of six inspections within six years. This probability is not based on a yearly probability but is left as a probability of having a casualty within a six year period in order to better visualize the change in the probability. It further shows that the magnitude of the effect decreases as the number of inspections increases. On average though, and depending on the overall risk profile of the vessel, an inspection can potentially decrease the probability of a very serious casualty by approx. 5% per inspection.

Since the partial effects are in comparison to the benchmark of not inspected vessels, the positive signs for serious and less serious casualties could be explained with the fact that there is no significant difference between the ships that are not inspected or inspected in another regime (such as the Tokyo MoU, the Black Sea MoU or the Mediterranean MoU) and that there is room for improvement.

Figure 72 gives an overview of the effect of age and is based on one particular ship profile where age is measured in years of age of the vessel. One can clearly see that as the age of the vessel increases, the probability of having a very serious casualty increases by about 12% over a 35 year period which translates into about 0.35% per year. The age factor cannot be measured for serious and less serious casualties.

Figure 72: Effect of Age on the Probability of Casualty



The next area will try to evaluate if the correct ships are targeted for inspection and will partly built on the previous section. It compares inspected vessels with non inspected vessels.

6.4.3. Evaluation of the Target Factor: Can targeting be improved?

This section builds on *5.3. Overview of Inspections and Casualties* and looks further at some of the variables that are used to target ships for inspections such flag, class and ownership by comparing the probability of detention derived in part II of this thesis with the probability of casualty derived in this section. First, an overview of the possible magnitude of improvement for targeting will be provided by providing a combined graph of Figure 55 and Figure 56 presented at the end of Chapter 5.

Figure 55 has shown that about 2.4% of the world fleet eligible for port state control are ships that have not been inspected but had a casualty. In addition, 1.7% of the vessels had a casualty and was inspected without any related time frame while 2.5% of the vessels were inspected six months prior to a casualty. What is interesting to notice but which is not shown in this graph is that based on the individual port state control inspections, 54% of all inspections were inspections with zero deficiencies while when aggregated by ship and taken as a summary of all inspections performed on vessels, this percentage reduces to 16% of all inspections for the time frame 1999 to 2004. On the other hand, if only looking at the last inspection six months prior to a casualty as shown in the figure with 2.5% of the total world fleet, 52.3% of these vessels were ships with zero deficiencies.

The portion of ships which have been inspected can be understood as the ships that have been targeted for inspections of which a certain portion was assumed to be sub-standard. About 16% of all inspected vessels had zero deficiencies over the time period in question and these ships might have been ships which should not have been targeted (4,221 ships). On the other hand, looking at ships which have been inspected six months prior to a casualty (2,321 ships) where 52.3% of these vessels had zero deficiencies (1,215 ships) and the rest had deficiencies. This changes the 4,221 ships which should not have been targeted into 3,006 vessels or approx. 501 ships per year.

It is further worth noticing that out of the 1,106 vessels (2,321 – 1,215) with deficiencies, 14.6% were detained (162 vessels) and had a casualty. This portion could be understood as ships that have been targeted correctly and identified as sub-standard vessels but for some reason, detention was not sufficient to increase the safety standard of the vessel to prevent a casualty. The remaining amount of the vessels which have been inspected and where deficiencies were found are the vessels where the effect of inspections decreased the probability of a casualty which is the partial effect of the regressions shown in this section of the thesis. In number of vessels, this amounts to approx. 18,874[96] vessels or 3,146 ships per year. Figure 73 then visualizes the discussion above and presents a summary of the magnitude of possible improvement areas for port state control.

The figure is only based on ships that are relevant for port state control (excluding the fishing fleet > 400gt) and is a summary of the total time frame. The graph shows several groups out of which *group 1* of about 36% of the vessels eligible for inspections are identified not to have been problematic over the time period and have also not been targeted by the regimes in question. About 7% of the vessels eligible for port state control have been targeted over the time frame but did not have a casualty and also no deficiencies and therefore represent a group of over-inspected vessels *(group 2)*.

Group 3 of 43% of the vessels can be identified to belong to a group where inspections are effective in decreasing the probability of casualty where this effect can be measured for

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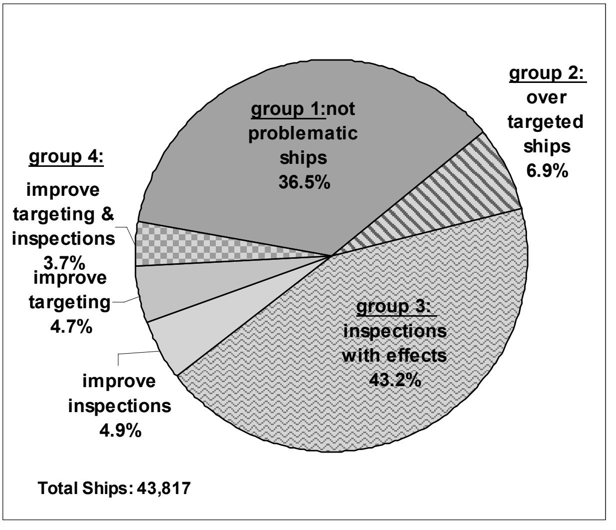
[96] 21,880 total inspected ships with no casualty minus 3,006 ships with no deficiencies

very serious casualties and estimated (depending on the basic ship risk profile) to be a 5% decrease per inspection. This category can also represent further room for improvement but shows that port state control is effective.

Figure 73: Improvement Areas for PSC eligible ships (1999-2004)



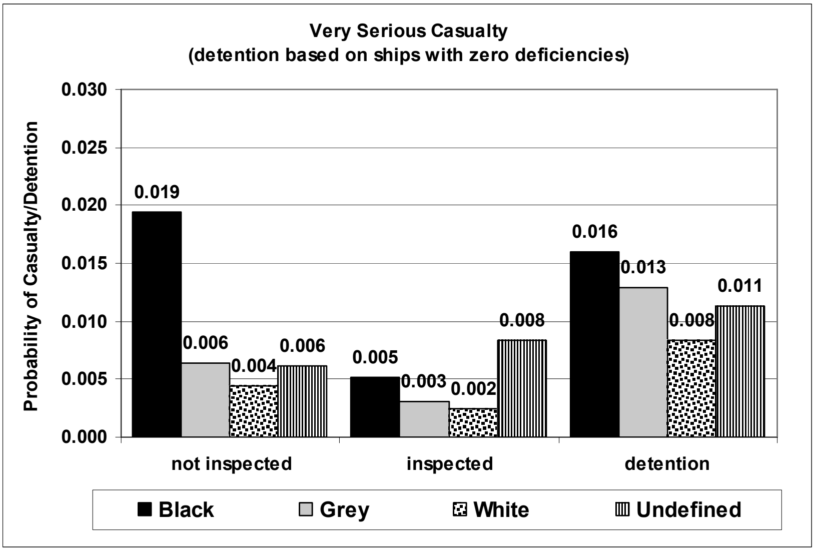
Note: Based on only PSC relevant ships and based on total time frame (1999-2004)

Group 4 is split into three portions. The first portion is 4.9% of PSC eligible vessels which are the amount of ships that have been targeted correctly but since they had a casualty within six month after the inspection, the enforcement could be improved. The second portion shows 4.7% of ships which had a casualty but were not inspected and where targeting could be improved. Finally, the last category shows a grey area. In this group, ships had a casualty but regardless of the time frame. Therefore, inspections and possibly targeting could be improved. Most improvement to decrease the probability of a casualty can be achieved by concentrating on the categories in group 4 by shifting the emphasis from group 2 to group 4.

Figure 74 and Figure 75 both show the average probability of a very serious or serious casualty of flag state groups such as black, grey, white and undefined for flags that are not on the Paris MoU list. The Paris MoU classification is used since about half of the data derives from the Paris MoU dataset. The graphs show the difference between inspected and non inspected ships which is clearer for very serious casualties than for serious casualties. Black listed flag states have a higher probability of having a very serious casualty followed by grey and white listed flag states. The same picture applies to detention (based on ships with zero deficiencies).

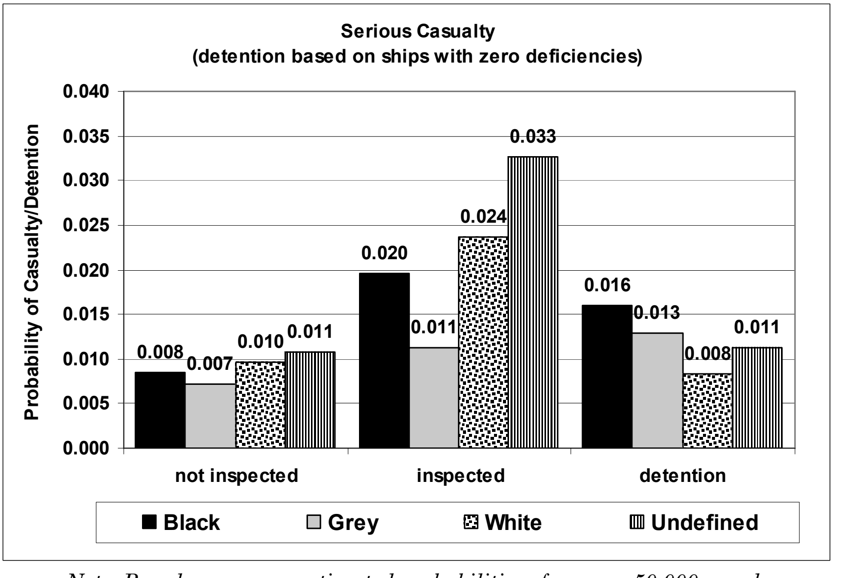
For serious casualties, the picture changes and indicates that these vessels show a higher probability of having a serious casualty. It seems to indicate that these vessels are targeted for inspection but that there is less effect of an inspection on decreasing the probability of casualty (as can be observed for the very serious casualties). In order to look into this topic further, Figure 76 was produced and shows a list of top 30 flag states and their associated probability of casualty and detention. Flag states with relative high probability of detention in relation to casualty are Mongolia, Cambodia and North Korea.

Figure 74: Probability of Very Serious Casualty per Flag State Group



Note: Based on average estimated probabilities of approx. 50,000 vessels

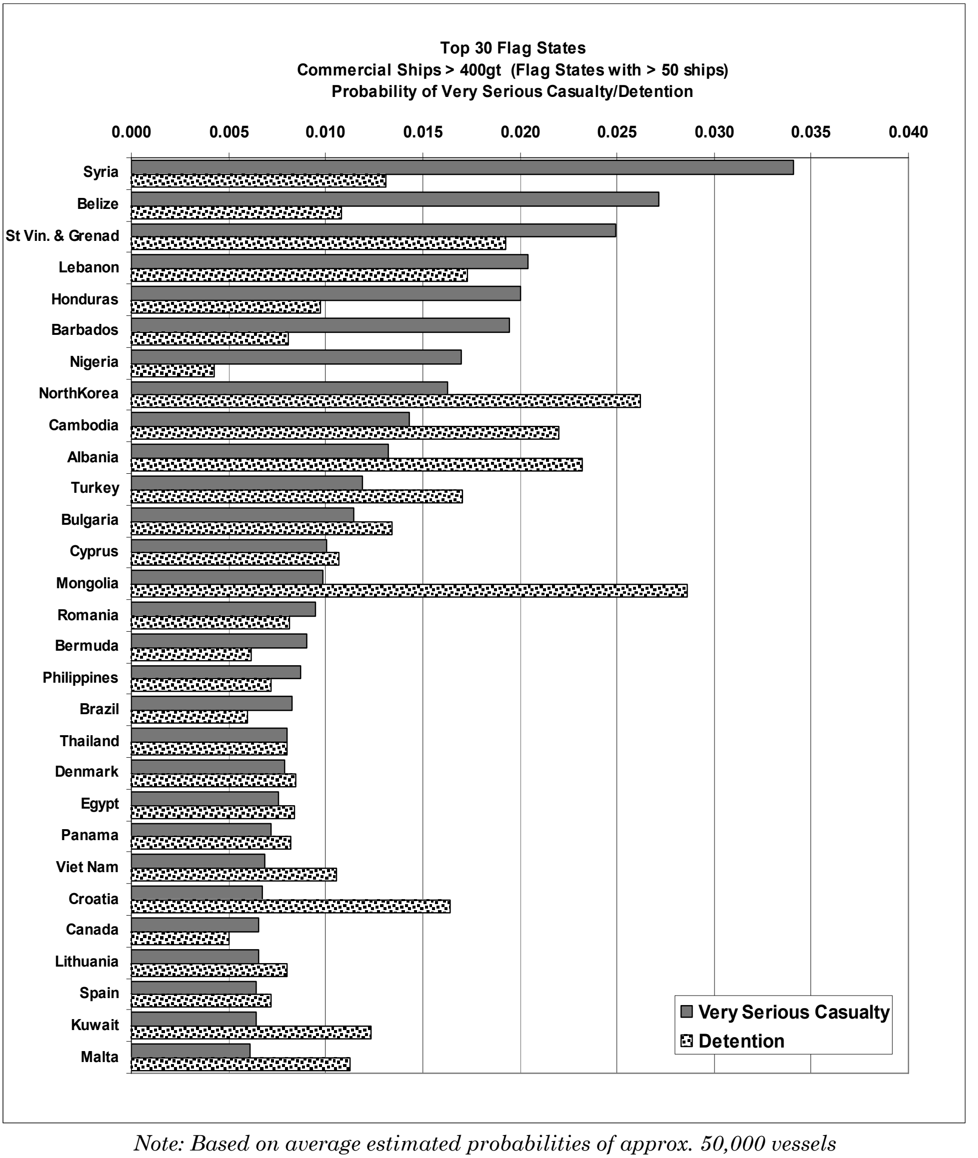
Figure 75: Probability of Serious Casualty per Flag State Group



Note: Based on average estimated probabilities of approx. 50,000 vessels

The graph also gives the probability of detention based on ships with zero deficiencies which serves as a basic risk profile based on the ships. The probability of detention for the top seven flags is lower than the probability of a very serious casualty and then increases above it for a group of flag states. The graph is based on flag states with more than 50 registered vessels.

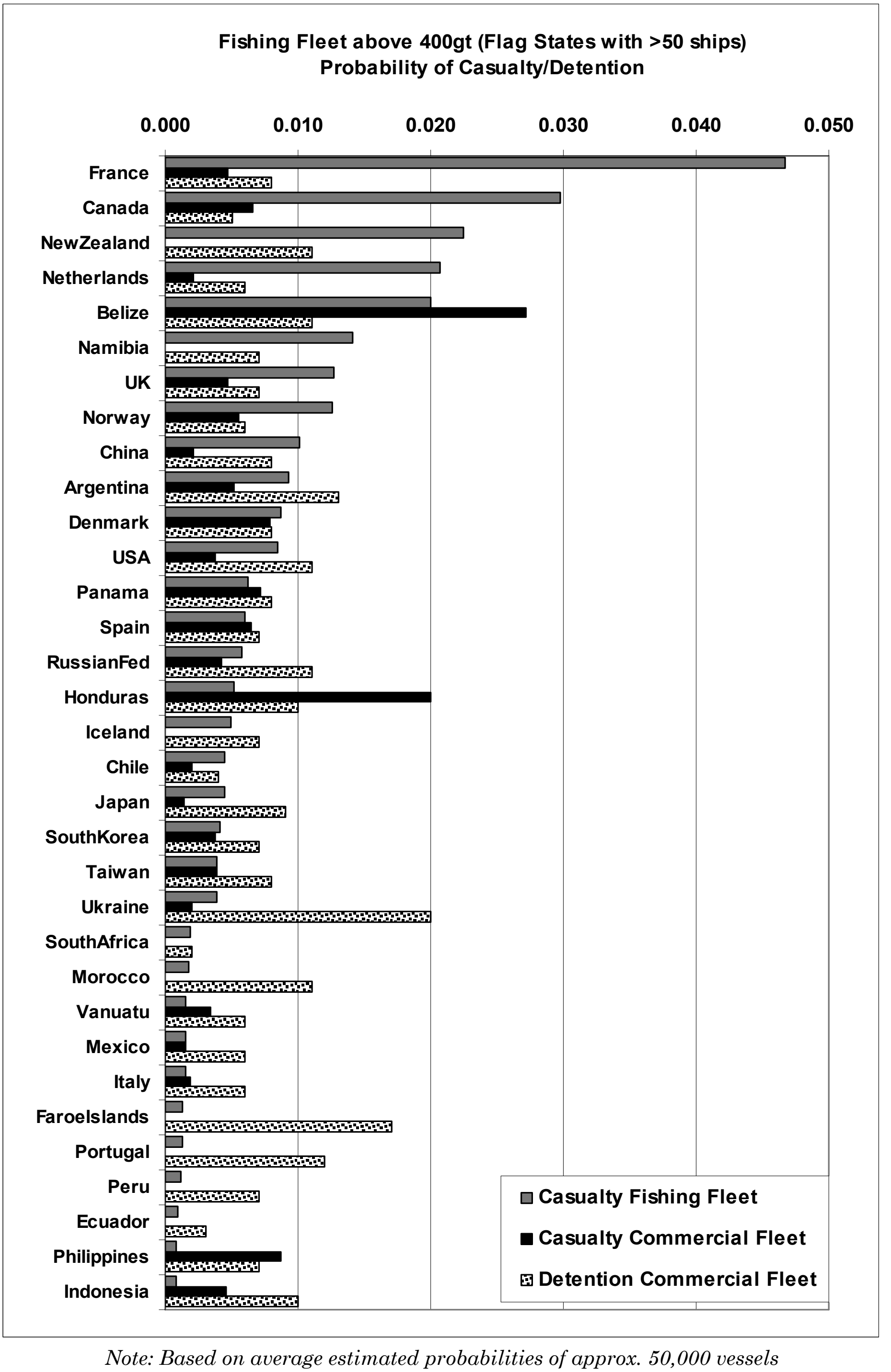
Figure 76: List of Top 30 Flag States: Very Serious Casualty



Note: Based on average estimated probabilities of approx. 50,000 vessels

Figure 77 shows the picture for the fishing fleet above 400gt. The graph shows the probability of casualty based on the fishing fleet in comparison to the commercial fleet as well as detention. Flags with more than 50 ships are taken into consideration. For the probability of casualty, very serious casualties have been chosen since the author felt it would be more appropriate to compare this casualty with the probability of casualty of the fishing fleet. Detention in this graph is merely detention based on commercial vessels with the same flag and not fishing vessels.

Figure 77: List of Fishing Fleet (>400gt, more than 50 ships)

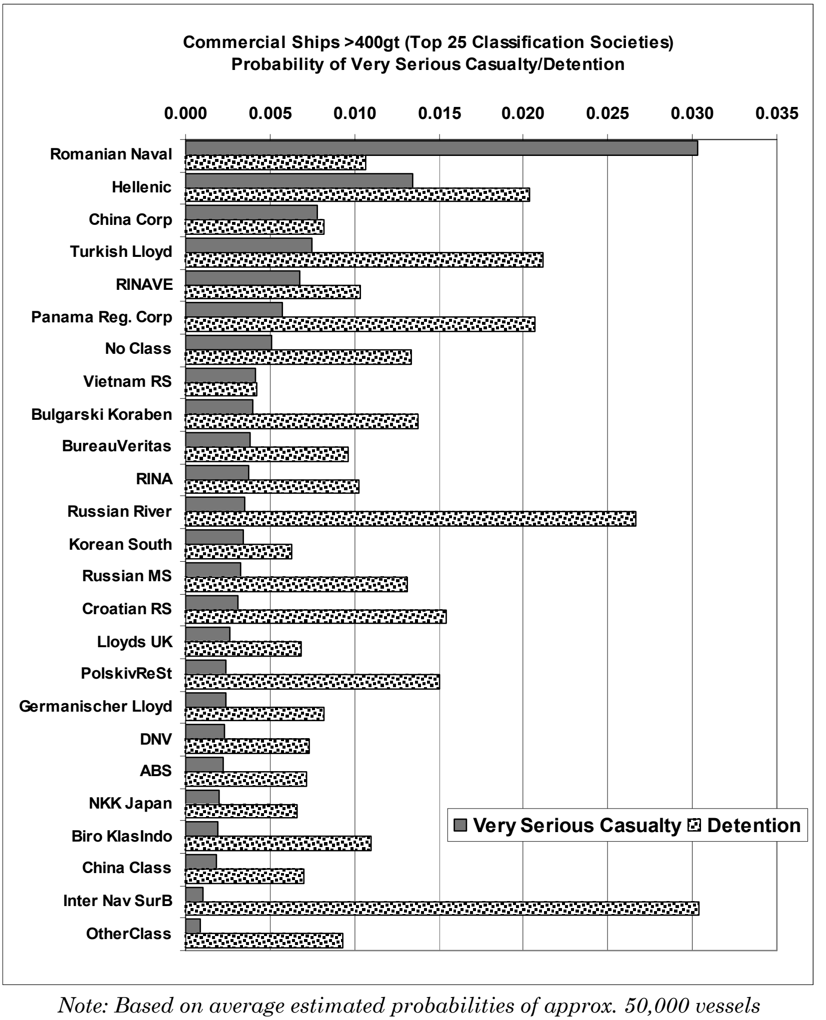


Note: Based on average estimated probabilities of approx. 50,000 vessels

The graph shows the main difference between the two industries where one is prone to be inspected and one is not or barely inspected (only factory ships) and that the flag by itself in this case cannot solely be the indicator of a high risk vessel since significant differences between the probability of casualty of the fishing fleet versus the commercial fleet under the same flag can be observed. For most countries, the probability of casualty of the fishing fleet is higher than for the commercial fleet. In reality this difference is expected to be higher when one would include the vessels below 400gt.

Figure 78 lists the top 25 classification societies and their probability of a very serious casualty and detention. In this graph, the difference between the two probabilities is much higher than with the flag states. Only three classification societies on this list have a count of below 50 namely, RINAVE, Panama Reg. Corp. and Romanian Naval. These three should therefore be interpreted with caution.

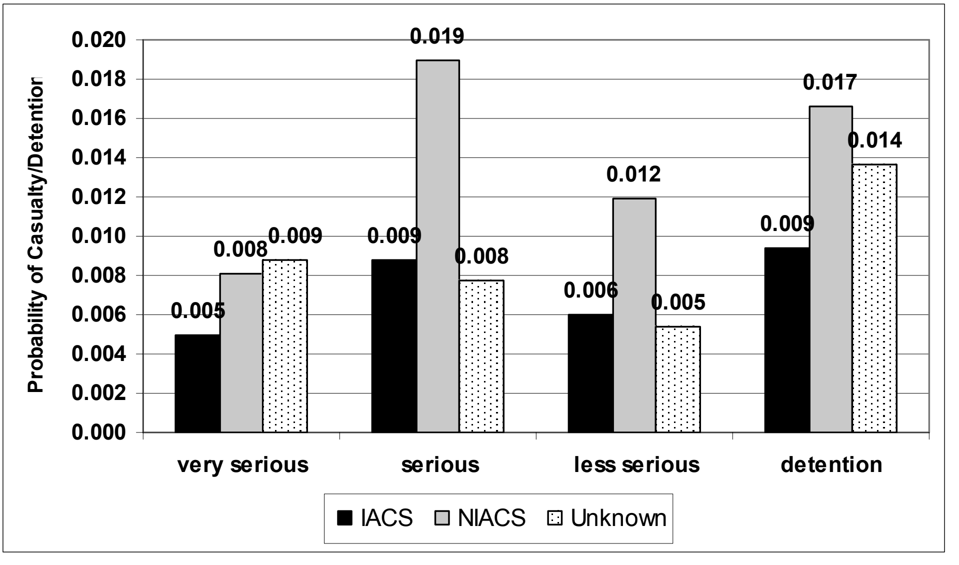
Figure 78: Probability of Casualty per Classification Society



Note: Based on average estimated probabilities of approx. 50,000 vessels

The overall picture is given in Figure 79 which is not split into inspected versus non inspected groups. For the graphs of the classification societies, the interpretation has to be careful due to the lack of some data. From the total casualty dataset, about 25% of the classification societies were missing which is indicated with unknown in the graph. Most of these observations are assumed to be Non-IACS class versus IACS class since one of the data providers does not indicate Non-IACS class. In general, ships classified with IACS class show a lower probability of casualty for all three categories and detention versus Non-IACS class.

Figure 79: Probability of Casualty and Class Groups



Note: Based on average estimated probabilities of approx. 50,000 vessels

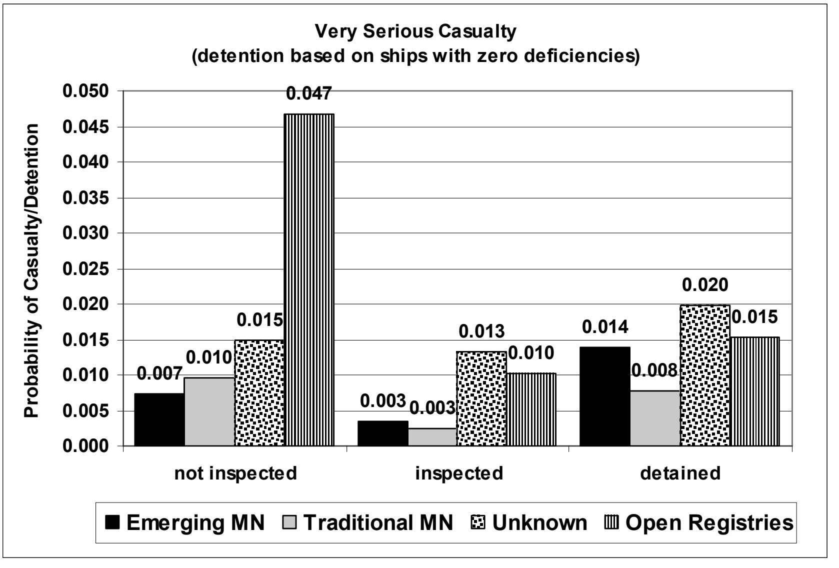
In addition, the casualty and inspection data did not indicate the various types of classification societies a vessel can have which could be up to 4. The analysis is only based on the main class at the time of inspection or casualty which is primarily the classification society the vessel is classed in and does not necessarily has to be the classification society of ISM or ISPS[97]. An analysis which reflects the different types of classification societies per vessel are left as a recommendation for further research.

Figure 80 and Figure 81 look at the ownership of a vessel and it is interesting to notice that the highest probability of a very serious casualty lies with owners from open registries followed by unknown ownership, traditional maritime nations and emerging maritime nations. The difference between inspected and non-inspected vessels is also clear while traditional maritime nations show the lowest probability for inspected vessels which is in line with the probability of detention. For serious casualties, the order changes as well as the difference between the groups. Appendix 25 shows the probability of a very serious and serious casualty per DoC company country of residence. Since not enough data was available in the casualty dataset, it is based on the inspection dataset and therefore only shows inspected vessels. The graph is only based on countries that showed more than 100 ships. It gives further an indication on how the probability of

[97] ISPS for the purpose of this analysis is indifferent since security is not included in this thesis.

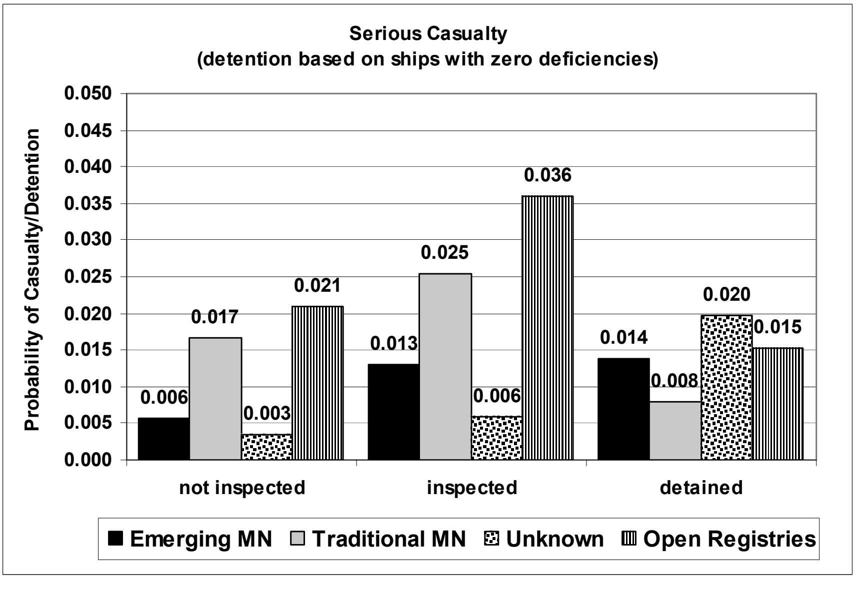
casualty can be linked to ownership. Not all regimes have this variable incorporated into the target factor to target vessels for inspection. More detailed research in this area is recommended. At this stage, company data was available but not used for the purpose of this study but the country of residence was used instead.

Figure 80: Probability of Very Serious Casualty per Ownership Group



Note: Based on average estimated probabilities of approx. 50,000 vessels

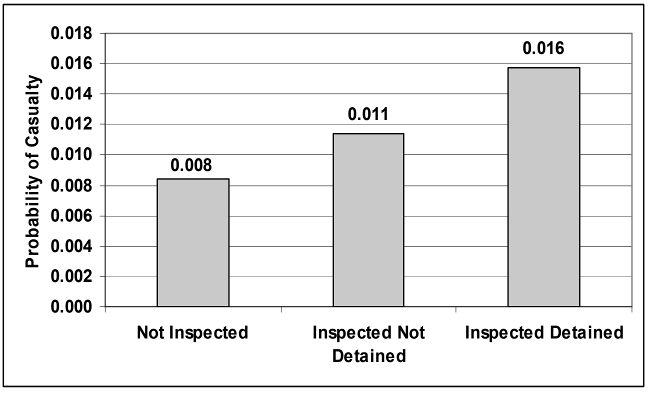
Figure 81: Probability of Serious Casualty per Ownership Group



Note: Based on average estimated probabilities of approx. 50,000 vessels

Figure 82 shows the probability of casualty for ships that have not been inspected versus ships that have been inspected and detained (or not detained). It is based on an average probability and not split into seriousness. In general, ships not inspected by port state control show a lower probability of casualty while ships that have been inspected and detained show a higher probability. Detained vessels show the highest probability of a casualty. The graph confirms that on average, detained vessels seems to be more risk prone towards the probability of casualty but it also shows that detention by itself does not seem to have a negative effect on the probability of casualty. A possible room for improvement is therefore the follow up on detentions and deficiencies such as maybe the correct implementation of the safety management onboard. The partial effect of detention is analyzed in the detailed regressions in Chapter 7: Probability of Casualty-Refined View.

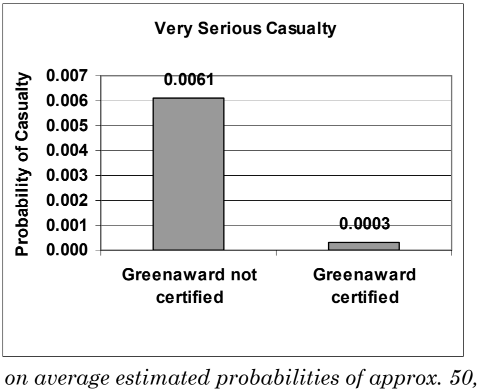
Figure 82: Probability of Casualty of Detained versus not Detained Vessels



Note: Based on average estimated probabilities of approx. 50,000 vessels

Figure 83 gives the average probability of all ships that were certified by the Greenaward Foundation versus ships that were not certified by the Greenaward Foundation and Figure 84 shows the same picture based on ships that have been inspected by Rightship (vetting inspections). For Greenaward certified ships, this applies for oil tankers while Rightship inspected primarily bulk carriers and some oil tankers.

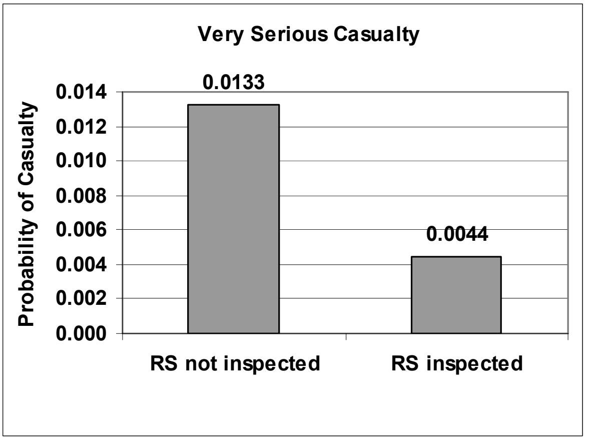
Figure 83: Probability of Casualty: Greenaward Certified (oil tankers)



Note: Based on average estimated probabilities of approx. 50,000 vessels

Both graphs show a difference in the probability of a very serious casualty for ships that have not been certified (inspected) versus ships that have been certified (inspected). While the partial effects will be looked at in the next chapter in detail, this should provide some indication on possible improvements for targeting vessels since it can easily be incorporated into targeting matrices of port state control.

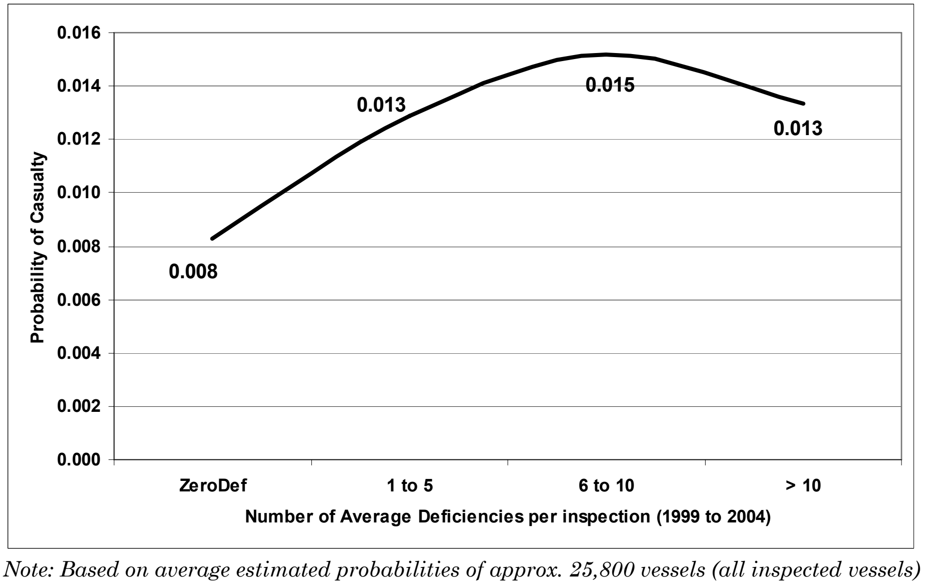
Figure 84: Probability of Casualty: Rightship Inspected (bulk carriers and oil tankers)



Note: Based on average estimated probabilities of approx. 50,000 vessels

Figure 85 brings the probability of a casualty in relation to the number of deficiencies a vessel can have during an inspection.

Figure 85: Probability of Casualty and Number of Deficiencies



Note: Based on average estimated probabilities of approx. 25,800 vessels (all inspected vessels)

One can see that overall, the probability of having a casualty increases as the number of deficiencies increases to a peak of 6 to 10 deficiencies per inspection. This graph is based on the total time frame (1999 to 2004) and all port state controlled inspected vessels. It shows that port state control does find deficiencies on high risk vessels and that a vessel with more deficiencies also has a higher probability of casualty with a maximum of 10 deficiencies per inspection. The probability then decreases slightly which can be interpreted with the fact that vessels with more deficiencies are more likely to be detained and will have to deal with the rectification of the deficiencies. The average probability of detention (based on results from Chapter 4 of this thesis) for ships with more then 10 deficiencies lies at 0.45 compared to 0.13 for an average of 5 to 10 deficiencies per inspection.

6.5. Summary of Findings: Casualty Overall View

About 32% of all port state control relevant casualties between 1999 to 2004 show signs of a casualty first event in engine related areas. Per ship type and for the time period 1993 to 2004 in aggregated form and regardless of port state control relevance, general cargo ships are leading with 37.9 % followed by dry bulk (15.7%), oil tankers (11.4%) and container ships (7.3%). The fishing fleet shows a higher amount of percentage with 6.9% to the total. Passenger vessels including hydrofoils and ferries are by 9.9%. With respect to the casualty locations, a high risk area is West Africa, the Indian Ocean region, the North Atlantic East region and the South China Sea.

Improvement for port state control has been identified in the area of targeting and possibly the inspections itself. About 36% of the vessels eligible for inspections are identified not to have been problematic over the time period in question and have also not been targeted by the regimes in question. About 7% of the vessels eligible for port state control have been targeted over the time frame but did not have a casualty and also no deficiencies and therefore represent a group of over-inspected vessels where intervals of inspections could be increased.

About 43% of the vessels can be identified to belong to a group where inspections are effective in decreasing the probability of casualty where this effect is strongest for very serious casualties and estimated (depending on the basic ship risk profile) to be a 5% decrease per inspection. This category can also represent further room for improvement but shows that port state control is effective. Finally, about 4.9% of PSC eligible vessels have been targeted correctly but since they had a casualty within six month after the inspection, the enforcement could be improved. Another portion of 4.7% of ships had a casualty but was not inspected. This is an area where targeting could be improved.

The mean amount of deficiencies found at least six month prior to a casualty lies by 4.3 for black listed flag states versus 2.7 for grey and 1.7 for white listed flag states. Per seriousness of casualty, detained vessels show significantly higher amount of deficiencies (17 deficiencies for very serious) versus not detained vessels (3 deficiencies).

Regression analysis based on inspected and not inspected vessels reveals that the average probabilities of a casualty are by 0.06% (very serious), 1.6% (serious) and 1% (less serious) compared to 0.07% for the fishing fleet above 400gt. Comparing an industry that is hardly or not inspected (the fishing fleet) with commercial fishing, one can see that performance of flag states changes accordingly. Flag states that are normally exposed to inspections under the port state control regime seem to perform better than if they are only exposed to their own flag state inspections which can be seen with the white listed flag states showing the highest probability of casualty under the fishing fleet.

With reference to ship types, general cargo vessels seem to show the highest probability of a very serious and serious casualty of 1% and 2% respectively compared to tankers with below 0.5% for very serious casualties and 1% for serious casualties. Container vessels show the lowest risk in all three types of casualties. Comparing ships that have been inspected with ships that have not been inspected, the strongest difference can be seen with general cargo vessels and dry bulk carriers for very serious casualties and least of the effect can be seen with tankers and container vessels. Vetting inspections for certain ship types such as oil tanker and dry bulk carriers both show a negative effect on the probability of casualty.

With respect to the target factor, one can confirm that age is significant for very serious casualties and its effect is positive. One can clearly see that as the age of the vessel increases, the probability of having a very serious casualty increases by about 12% over a 35 year period which translates into about 0.35% per year. The average probability based on all ships changes according to ship type and general cargo ships and passenger vessels seem to show much of the variation with respect to age. Tonnage is also only significant for very serious casualties but is negative indicating that a smaller vessel seems to be at higher risk than larger vessels which goes in line with the general cargo vessels being more high risk prone.

The probability of casualty changes per ship type and confirms that general cargo vessels are ships with the highest probability of a casualty which is confirmed by the probability of detention. Black listed flag states or non inspected ships show a higher probability of a very serious casualty compared to grey and white listed flag states while the same does not hold for serious and less serious casualties. It might indicate that the target factors are targeting high risk vessels but are less effective in decreasing the probability of a serious and less serious casualty. This is confirmed with the partial effects which are only negative for very serious casualties.

With respect to classification societies, the probability of a casualty for Non-IACS class is higher than for IACS class and is also confirmed by the probability of detention. For ownership groups and in comparison of inspected to non–inspected vessels, highest probability of casualty lies within owners from open registry countries followed by unknown owners, owners from traditional maritime nations and emerging maritime nations. This does not follow the probability of detention where owners from traditional maritime nations show the lowest probability of detention.

Detained vessels show the highest probability of casualty compared to vessels that have been inspected but not detained and vessel that have not been inspected. The average probability of a very serious casualty of ships that are Greenaward certified or have been inspected by Rightship is lower than for non-certified or non-inspected vessels. A variable indicating both can be easily incorporated into target factors of port state control. In addition and based on average probabilities, the probability of casualty increases from about 0.1% to 0.2% as the number of deficiencies increases. This is irregardless of the time frame of the inspection and is based on the total inspection time frame of about six years.

The variable indicating if the ship type changed its class during its course of life is significant and negative for all types of casualties. This could mean that in general, if a class is changed, an inspection is performed which might have a positive influence on the quality of the vessel. On the other hand, the next variable indicating if class was withdrawn shows a positive effect which means that these types of vessel have a higher probability of having a casualty.

Change of flag does not seem to be significant while change of ownership is significant and positive for all types of casualties but in particular for very serious casualties. This could indicate that a change of the vessel into second hand ownership or into a segment of the market where less money is spent on safety increases the probability of a very serious casualty. The variable double hull is not significant for any type of casualty.

The next chapter will look at a more detailed view of the effect of inspections themselves on the probability of having a casualty as well as port state control deficiencies in relation to casualty first events.

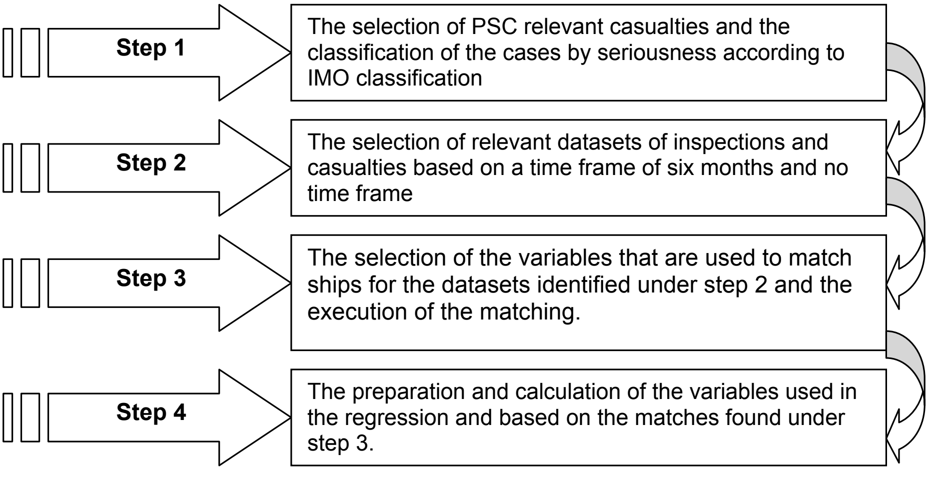
Chapter 7: Probability of Casualty-Refined View

This chapter further refines the general casualty models and tries to measure the actual effectiveness of some of the inspection variables on the probability of having a casualty by comparing ships that have been inspected with a casualty with ships without a casualty and based on their ship history. It will further also look at deficiencies that were found during inspections in relation to casualty first events. The first part will explain the criteria and decision processes for the preparation of the dataset and the second part will explain the model used for the various types of regressions and visualization of the results.

7.1. Description of Methodology for Data Preparation

Figure 86 provides an overview of the steps that were taken in order to perform the analysis which will be described in the next chapter. Four steps could be identified and will be explained in the chapter to come in detail. The graph should merely give an overview to the reader in order to provide easier guidance to follow through the whole process.

Figure 86: Description of Methodology Used



The *first step* is the same as mentioned in the previous chapter and will 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 where the fishing fleet is not taken into consideration here.

7.1.1. The Selection of Relevant Datasets to be Used

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 32 below.

Table 32: 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.

7.1.2. Methodology Used to Match Ships

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 quite large. In doing the match, the first three variables listed in Table 33 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. The match is performed in order to obtain a more refined view of the variables of interest (the variables which describe the quality of an inspection). In this way, twin ships are compared and variables which normally would also have an effect towards the probability of casualty such as e.g. age, ship type, flag, owner or class are cancelled out and are not interpreted in the end models.

Table 33: 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.

To merge the ships, these changes were taken into consideration and the results can be seen in Table 34. To facilitate the matching, the year built and gross tonnage was split into groups which represent ranges and can be seen in Table 35 and with their respective counts of ships in each of the groups and datasets. For the construction year, 11 groups in ranges of five to ten years where identified and for gross tonnage, 44 groups were created (ranges of 1000 gt to 5000 gt).

Table 34: Ship Type Groups for Matching

Groups	Ship Types	Ship Count/Group		
		Total Ships	Casualties & Inspections	Inspections Only
1	container	2049	309	1740
2	dry bulk	4170	575	3595
3	general cargo	9236	1725	7511
4	other	3713	431	3282
5	passenger	865	210	655
6	tanker	5803	706	5097
	Total Ships	**25836**	**3956**	**21880**

Table 35: Year Built Ranges for Matching

Groups	Year Built Ranges	Increment	Ship Count/Group			Ship Age
			Total	Casualties & Insp.	Inspections Only	
1	1879-1939		28	6	22	70
2	1940-1949	10 years	22	3	19	60
3	1950-1959		172	36	136	50
4	1960-1969		1126	187	939	40
5	1970-1974	5 years	1821	290	1531	30
6	1975-1979		3989	723	3266	25
7	1980-1984		4424	800	3624	20
8	1985-1989		3179	504	2675	15
9	1990-1994		2984	472	2512	10
10	1995-1999		4131	615	3516	5
11	2000-2004		3960	320	3640	0
		Total Ships	**25836**	**3956**	**21880**	

Table 36: Tonnage Ranges for Matching

Groups	Ranges From-To			Increment	Count		
					Total	Casualties	Inspections
0	below		1000	plus 1000	2139	217	1922
1	1001	to	2000		2287	444	1843
2	2001	to	3000		2204	363	1841
3	3001	to	4000		1369	215	1154
4	4001	to	6000	plus 2000	1866	295	1571
5	6001	to	8000		1202	207	995
6	8001	to	10000		966	171	795
7	10001	to	13500	plus 3500	1550	243	1307
8	13501	to	17000		1778	301	1477
9	17001	to	20500		1318	213	1105
10	20501	to	24000		1208	213	995
11	24001	to	27500		1204	155	1049
12	27501	to	31000		1012	129	883
13	31001	to	34500		387	70	317
14	34501	to	38000		891	153	738
15	38001	to	42000	plus 4000	1016	130	886

Table 36 continued					Count		
Groups	Ranges From-To			Increment	Total	Casualties	Inspections
16	42001	to	46000		316	38	278
17	46001	to	50000		261	39	222
18	50001	to	54000		447	84	363
19	54001	to	58000		378	46	332
20	58001	to	62000		154	21	133
21	62001	to	66000		166	13	153
22	66001	to	70000		140	14	126
23	70001	to	74000		86	22	64
24	74001	to	78000		250	38	212
25	78001	to	82000		247	29	218
26	82001	to	86000		145	11	134
27	86001	to	90000		163	11	152
28	90001	to	95000	plus 5000	141	22	119
29	95001	to	100000		29	4	25
30	100001	to	105000		20	3	17
31	105001	to	110000		19	1	18
32	110001	to	115000		36	2	34
33	115001	to	120000		13	2	11
34	120001	to	125000		7	1	6
35	125001	to	130000		12	1	11
36	130001	to	135000		22	2	20
37	135001	to	140000		17	1	16
38	140001	to	145000		18	0	18
39	145001	to	150000		50	5	45
40	150001	to	155000		53	6	47
41	155001	to	160000		149	18	131
42	160001	to	165000		77	3	74
43	165001	to	170000	and above	23	0	23
				Total Ships	**25836**	**3956**	**21880**

Using the three first variables and applying it to the datasets explained earlier, the table below gives an indication on the number of groups of the respective sets (2A and 2B) to be matched with the groups of set 1 (the inspected ships with no casualty).

Table 37: Overview of Groups used for Matching Ships per Dataset

Dataset	Total Records	Groups to Match
Set1 (inspected only)	148,557	1133 groups
Set2A (with casualty – 6m)	26,332	610 groups
Set2B (with casualty – total time frame)	38,711	764 groups

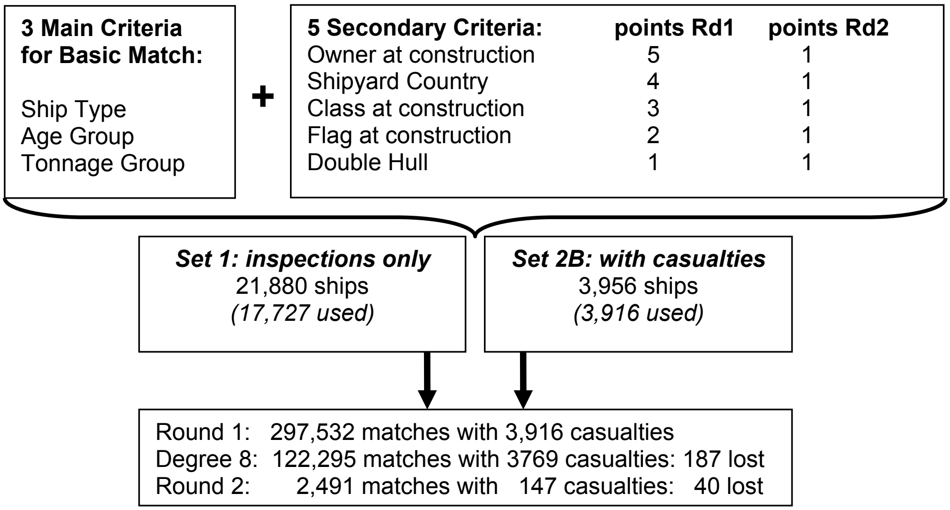
Note: based on ship type, age and tonnage groups

The remaining variables derive from data received by Lloyd's Register Fairplay[98] and are used to further refine the match. The matching was performed between Set 1 and Set2B using Oracle[99] and following the methodology which is visualized in Figure 87. Set 2A is a subset of Set 2B and is then extracted from the result of the basic match performed on Set

[98] A custom made match was performed by Lloyd's Register Fairplay to match the IMO numbers of the inspection/casualty dataset with vessel details at the time of construction for owner, class, flag and ship type.
[99] 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.

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 87: Visualization of Matching Methodology (per Ship)



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[100] with surveyors who have experience with new buildings, naval architects and one of the ship owner's associations[101].

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 38. 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

[100] For detailed list of interviews performed by the author can be found in the Bibliography.
[101] Dutch Royal Ship Owner's Association

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 38: 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 39 and are based on ship counts (a ship can have several casualties). The column indicating the ships with casualties lost is based on the number of ships with casualties as listed in Table 32 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. Therefore, it is decided to only use the dataset based on degree 8 and with the time frame of six months prior to a casualty.

Table 39: 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 40 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. It is a further detailed view on the overall effect that was given by the casualty models in Chapter 6 and in comparison to ships that were not inspected.

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 40: List of Twin Models and their Variables of Interest

Model Name	Types of Model/Data based on	Variables of interest
Type I Models (Total Models: 3)	Based on twins of ships inspected six months prior to a casualty Types are as follows*): o Very serious (5,826) o Serious (45,486) o Less serious (27,411)	Time in-between inspection Detention Deficiencies (less serious) Regimes (overall view) Vetting Inspections
Type II Model (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 Total # of observations: (52,150)	Time in-between inspection Detention Deficiencies per ship type Regimes (overall view)
Type III Models (Total Models: 5)	Based on casualties of a respective first event as identified in Chapter 5 in relation to the deficiencies found during a PSC inspection. Types are as follows: o Fire & Explosion (6,218) o Wrecked/Stranded/Grounded (19,131) o Collision/Contact (23,254) o Deck Related First Events (8,357) o Engine Related First Events (27,079)	Time in-between inspection Detention Deficiencies (refined view) 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 in *5.1. Selection of Port State Control Relevant Casualties* and is 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.

7.2. Explanation of Variables and Base Model Used

7.2.1. Variables Used for the Regression

The variables listed in Table 41 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).

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.

Table 41: Variables Used in the Twin Regressions (Type I, II and III models)

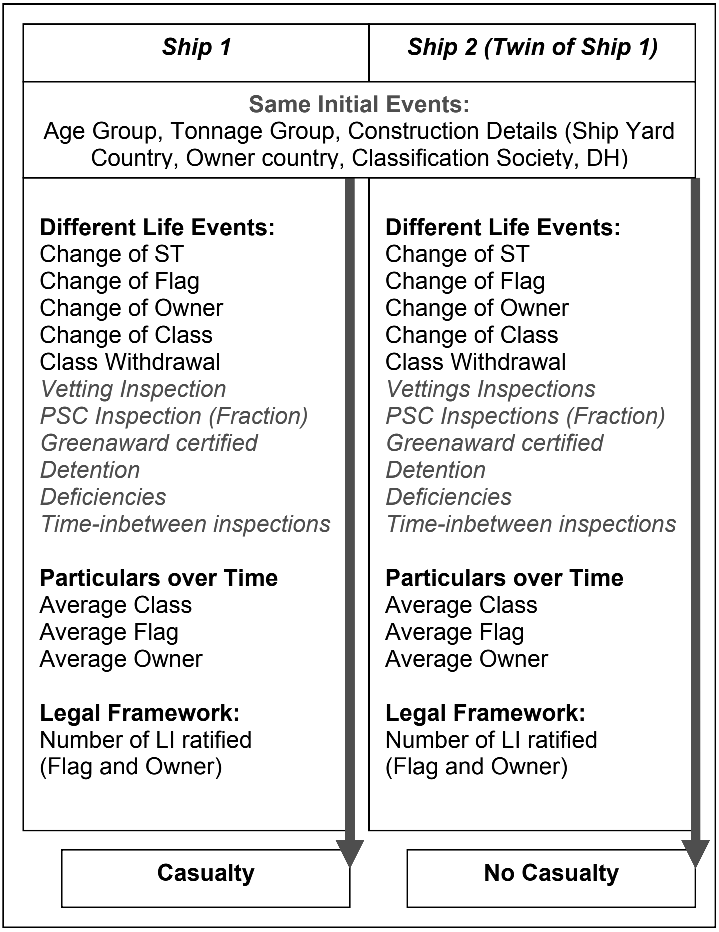
		Dependent Variable 1: Casualty: *This can be either per seriousness or by casualty first event*			**1/0**
		Independent Variables	**Number of Variable n_ℓ**	**Remark on Variable**	**Expected Sign**
	ℓ	***Block 1: Ship Particulars: included to account for target factors***			
Ln(Age)	1	Average age at 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

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 deficiency variables can be multiplied by ship types and increases the amount of variables accordingly which is shown in brackets in the table above.

Figure 88 visualizes the variable structure of the twin models by following a time line of a pair of vessels over its course of life. It further shows the difference of the combination of variables compared to the casualty models in Chapter 6 where ships were either inspected or not inspected. In these models, all ships are inspected. The variables of interest are the inspection variables. In addition, the variable indicating where the ship was inspected is used as a sum in Chapter 6 while in these models, it is a percentage fraction over all inspections that were performed on a vessel during the time period in question (1999 – 2004). It is believed that this more accurately splits the total inspection exposure across the regimes versus just adding the inspections up.

Figure 88: Visualization of Variable Structure: Twin Models



Note: Variables of interest are in italic

The model to estimate the effect of inspections on casualties is given in Equation 7 where the term $x_i\beta$ can change accordingly to the casualty model in question and is shown in Equation 7 in detail and based on the variables listed in Table 41.

Equation 7: Detailed Effect of Inspection on Casualties

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

The next section will provide a summary of the datasets and the results of each of Type I, II and III models. The visualization and interpretation part is then provided in summarized form for all models. The model produces probabilities on an individual ship level (i). The rest of the notation is as follows: ℓ represents the variable groups, n_ℓ is the total number of variables within each group of ℓ and k is an index from 1 to n_ℓ. A separate model was produced for each of the models listed in table Table 40 for either the seriousness of casualty or casualty first events.

Equation 8: Definition of term $x_i\beta$ of Casualty Detailed Model

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

7.3. Model Evaluation and Final Results

7.3.1. Type I & II Model: Casualty Refined View

Table 42 provides a split up of the ships with casualties into their seriousness which is the basis for the Type I and II models. 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).

Table 42: 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 I model (very serious) and type II model were tested for the presence of heteroscedasticity following the same procedure as explained in section *6.3. Model Evaluation and Final Results* for the variables age and tonnage. The null hypothesis (*H_o*) assumes homoscedasticity. A summary of the findings can be seen in Table 43 below and in Appendix 26 where *H_o* is rejected only for tonnage in the Type II model. Based on the process and the findings described in Chapter 6 for the very serious casualties, the presence of heteroscedasticity in these models for the variable tonnage and age are assumed not to have a serious influence on the results of the calculated probabilities and estimation is therefore not corrected by using Equation 6 but directly by Equation 7. The remaining statistics of the final models for Type I and II are then presented in Table 44 and in Appendix 27 and Appendix 28 for further detail. 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 statistics.

Table 43: 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

Table 44: 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
Includes Caribbean MoU and all ST		

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 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.

7.3.2. Type III Model: Casualty First Events and Deficiencies

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 45 below and the key statistics of the final models are given in Table 46. The actual regression outputs can be seen in Appendix 30 for all five models.

Table 45: 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*

Table 46: Summary of Statistics – Type III Models (6 month 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
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***	
	1 =	233	1 =	819	Engine rel. casualties	
	Total =	7771	Total =	27079	are w/o the Caribbean	
Cut Off	0.0300		0.0310		Fire: w/o container	
	LOG	**PRO**	**LOG**	**PRO**	WSG: w/o passenger	
Mc Fadden R2	0.079	0.079	0.084	0.085	and other ST	
% Hit Rate y=0	65.46	64.13	69.72	68.74	COCO: w/o other ST	
% Hit Rate y=1	67.81	69.96	63.00	64.22	Deck: w/o passenger	
% Hit Rate Tot	65.53	64.30	69.52	68.60	and other ST	
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

A ship can have more than one casualty first event and therefore a ship with a casualty can appear in each of the categories first events. The twins are the ships out of the ships with no casualty (21,880 ships) of the respective ships with a casualty.

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.

In addition, the LM test was performed similar to the Type I and II models and the results can be seen in Table 47 for the variables age and tonnage and in Appendix 29 for further reference. The null hypothesis (H_0) assumes homoscedasticity.

Table 47: Test Statistics for LM-Test: Type III models

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

Note: 1% significance level was used

The results show that there is no presence of heteroscedasticity in the form described under *6.3. Model Evaluation and Final Results* for the two variables in question. The next section will provide the visualization and interpretation part of all models.

7.4. Interpretation and Visualization of Twin Models

This section will summarize the results and visualize them in order to give a refined view on the effect of port state control inspection variables on the probability of a casualty (either by seriousness or casualty first event). It will look into the effect of inspections in general given they have been performed within a certain time frame, detention, the time in-between inspections and the deficiencies that were found in the inspections.

7.4.1. Refined View on PSC Inspections: Summary of Partial Effects

Table 48 lists a summary of the coefficients of the variables of interest for the Type I, II and 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 48: 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 relate. 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

- o 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[102] 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[103]. 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.
- o *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 II models. For the casualty first events, it is only significant for fire & explosion and engine related first events.
- o 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.
- o 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)

- o For *very serious casualties*, a positive effect can be found with code 1800 (gas and chemical carriers) and not other code remains significant.
- o 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).
- o 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).
- o 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).
- o 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)

- o 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.

[102] 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

[103] 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[104].
- 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 related operational 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 operational 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 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 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[105]. This finding confirms that there is problem with enforcing the legal conventions on chemical carriers. The next area will

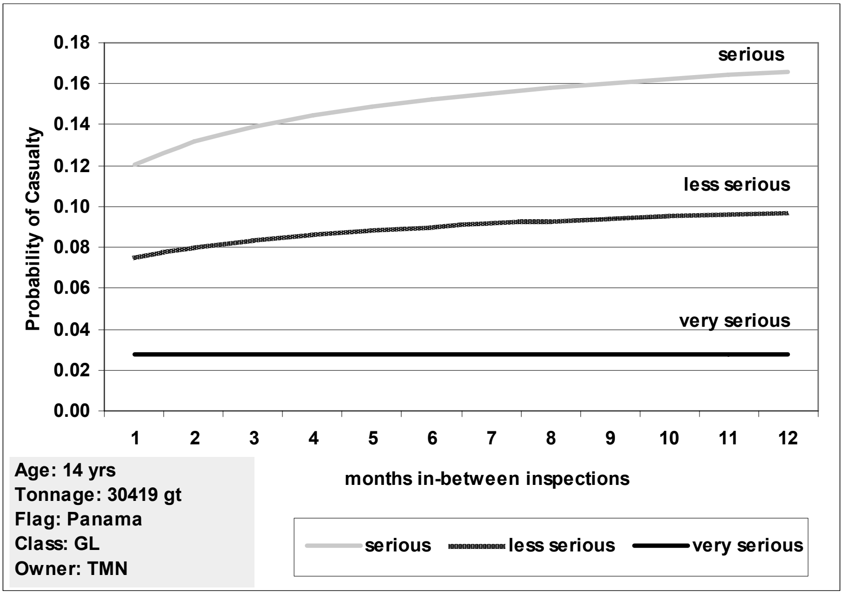
[104] code 700 and code 1400 are significant at the 5% level only
[105] The author attended as observer MSC (81) in May 2006, IMO, London

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.

7.4.2. The Effect of Time in-between Inspections

Figure 89 and Figure 90 both show the effect of time in-between inspections on the probability of a casualty per seriousness and casualty first events for a dry bulk carrier. As can be seen from the first graph, the time in-between inspections is not important for very serious casualties versus serious and less serious casualties and is only significant for fire & explosion and engine related first events. The strongest effect can be seen with serious casualties and only little effect can be identified with less serious casualties.

Figure 89: Effect on Time in-between Inspections: Seriousness



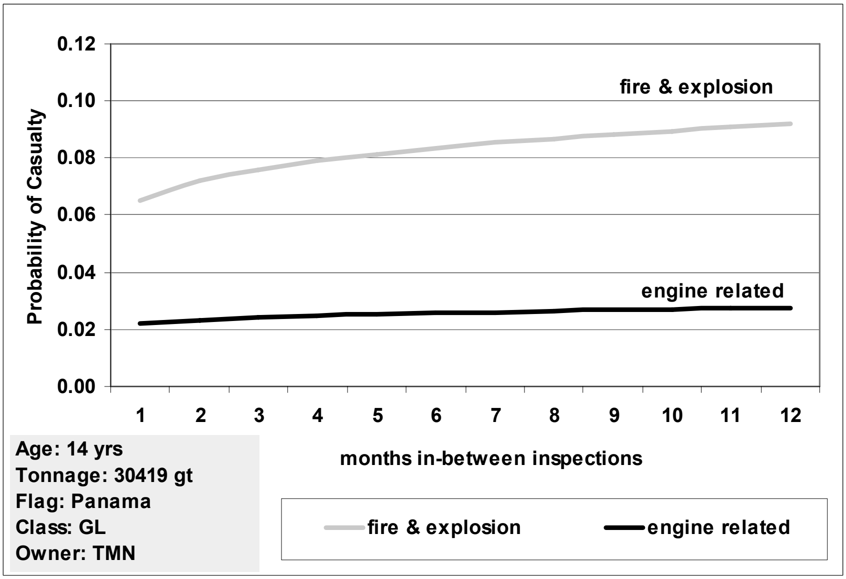
On average and regardless of the seriousness of the casualty, the probability of casualty increases by 2.3% within the time frame of one year. With respect to fire and explosion, the probability of casualty can increase as much as 2.7% within a year while this figure changes to barely 0.5% for engine related casualties.

7.4.3. The Effect of Inspections and Detentions

Summary of Partial Effects per Seriousness and First Events

The results given in Table 48 indicate that detention is only significant for less serious casualties and for casualties related to ships that are wrecked, stranded or grounded and or have engine related casualty first events. The fact that this variable is mostly not significant, especially for very serious and serious casualties indicates that detention cannot be measured of having a negative effect on the probability of casualty. One would expect to see a negative coefficient associated with this variable.

Figure 90: Effect on Time in-between Inspections: First Events



On the other hand and recalling the overall figures that were presented at the beginning of Chapter 5 where out of the 25,836 ships with inspections, 2,321 ships were inspected within six months prior to a casualty and 162 ships were detained (4% of vessels with casualty) over a six year time period, it might be difficult to interpret this coefficient and the effect is captured by the inspections itself. The difference between detention and a regular inspection is the enforcement of the rectification of the deficiencies. While detained vessels have to rectify them, not detained vessels do not have to do so and although the deficiency was found during an inspection, the inspection lacks on the enforcement side.

Table 49 is based on the Type I models where restrictions[106] using the Wald Test were tested for the variables indicating where the vessel was inspected to see if their 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 Indian Ocean MoU. 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.

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 91 to Figure 93 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

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

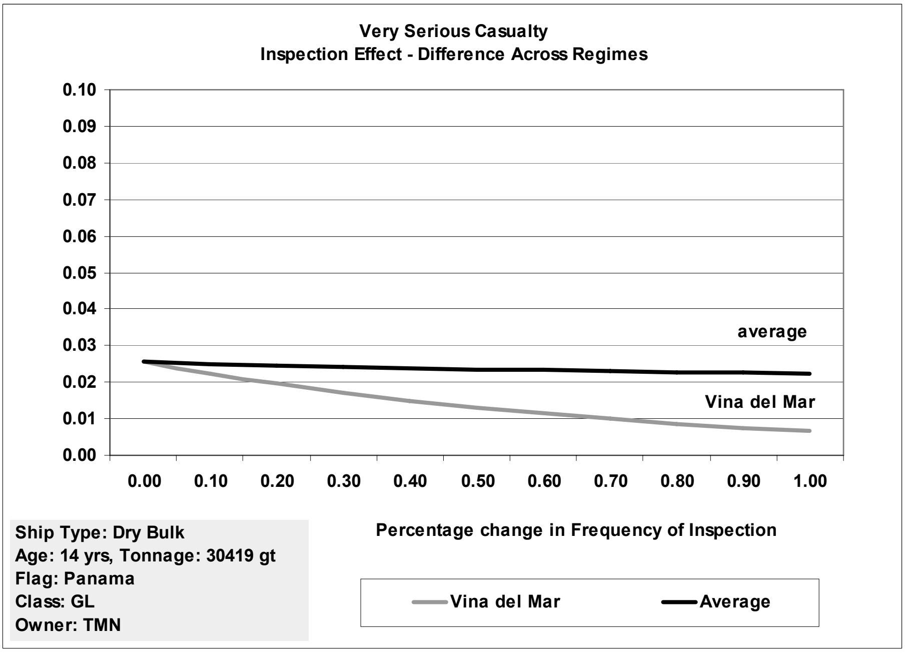
total inspection fraction of all of the regimes of a particular vessel where the Caribbean MoU had to be excluded from the models due to lack of data.

Table 49: 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 (0.0017) – *reject h_o*	AMSA=IMOU=VMOU (0.0286) - *do not reject h_o*
	AMSA=IMOU (0.0007)- *reject h_o*	AMSA=IMOU (0.1054)- *do not reject h_o*
	IMOU=VMOU (0.0013) - *reject h_o*	IMOU=VMOU (0.0086)- *reject h_o*
	AMSA=VMOU (0.07607) – *do not reject h_o*	AMSA=VMOU (0.2040) - *do not reject h_o*

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

Figure 91: Inspection Effect across Regimes: Very Serious



To visualize the differences, a particular ship is chosen and its associated probability of casualty is calculated. 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.

Figure 92: Inspection Effect across Regimes: Serious

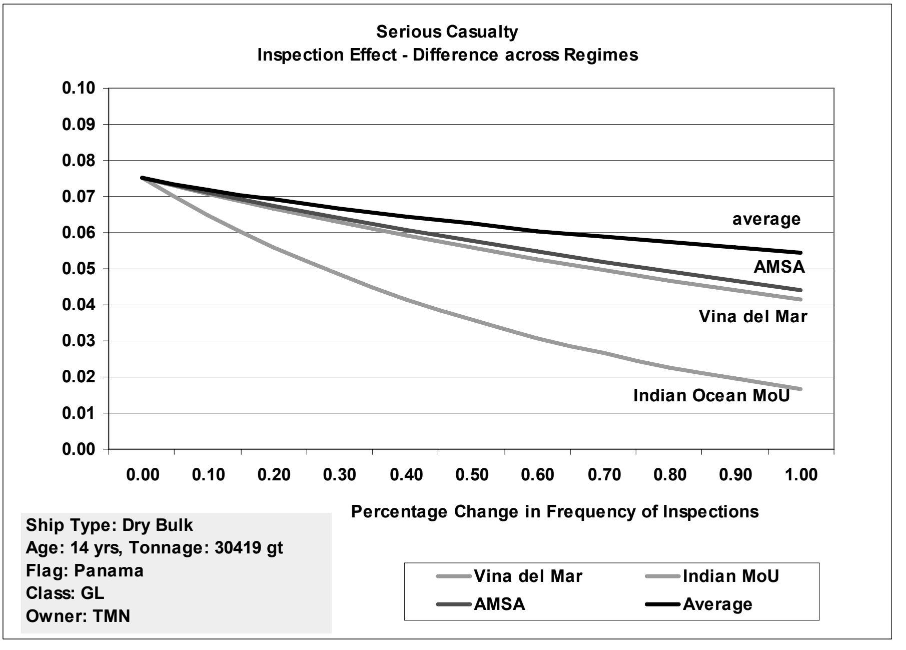
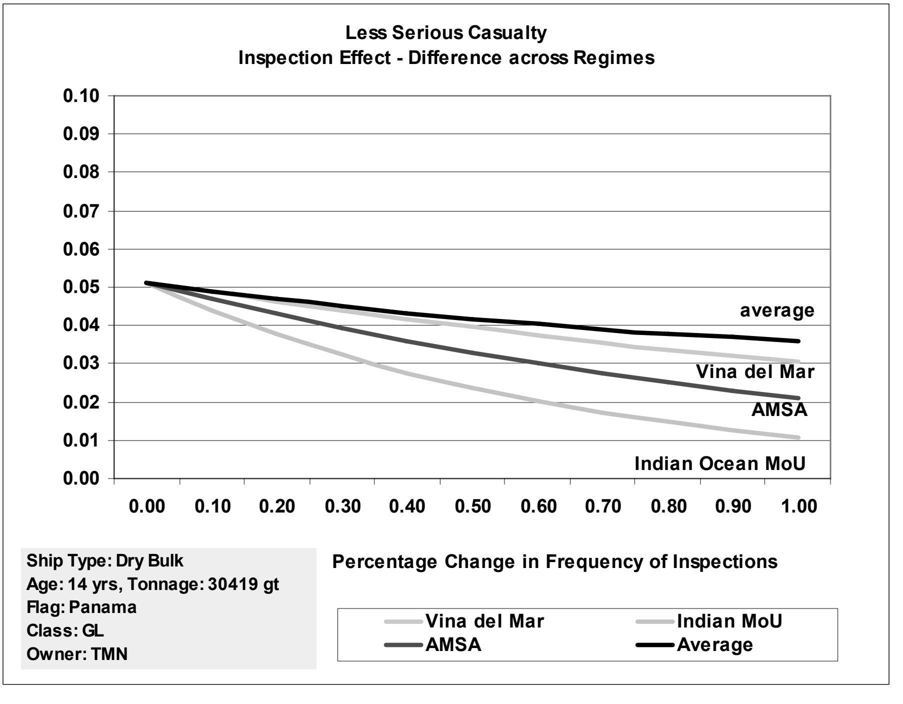


Figure 93: Inspection Effect across Regimes: Less Serious



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 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.

The Indian Ocean MoU region has been identified as a high risk area based on the descriptive statistics. This regime 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 50. 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 94) 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.

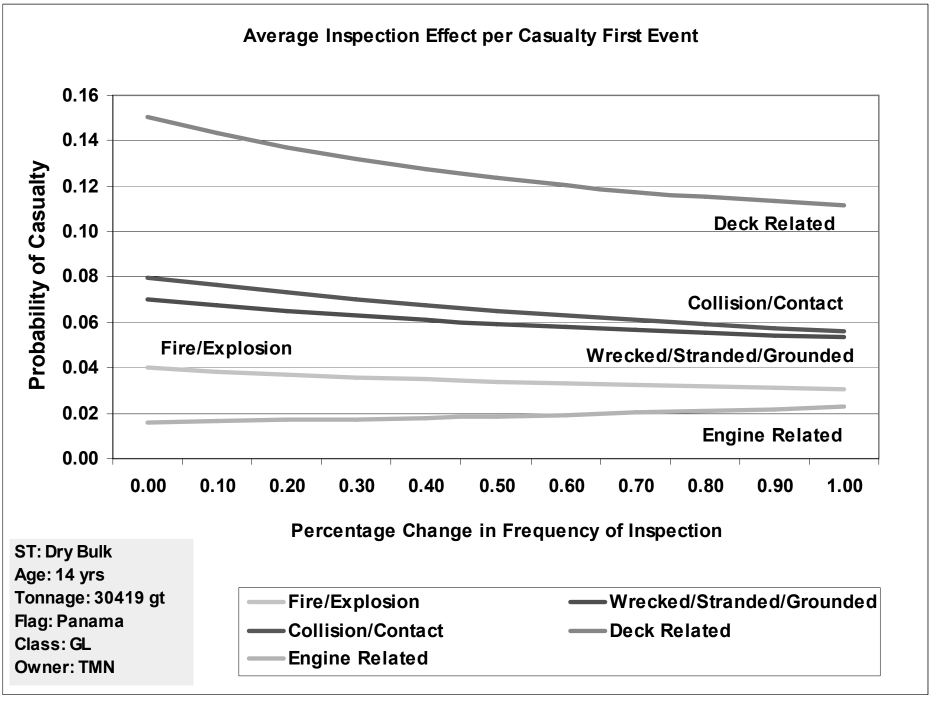
Table 50: Testing of Restrictions (Wald Test) - Inspection Variables: Type III Models

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

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.

Figure 94: Average Inspection Effect per Casualty First Event



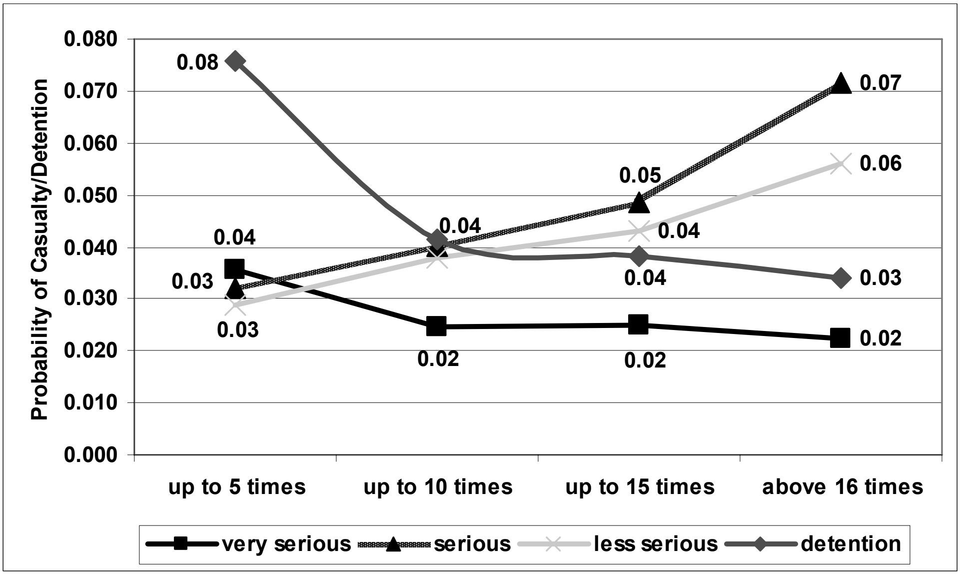
Frequency of Inspection and Detention

The next two graphs give an overview of the probability of casualty per frequency of inspection and detention given the ship has been inspected at least once within a six months time period. The probabilities are averages based on all inspected vessels or all detained vessels.

Figure 95 shows that the probability of detention decreases with the frequency of inspections while the probability of serious casualty increases from 3% to 7%. Less serious casualties increase by about 3% while very serious casualties decrease from 4% to 2% over time and with increased frequency of inspections. In essence, on could conclude that with increased amount of inspections, the probability of casualty does not necessarily decrease.

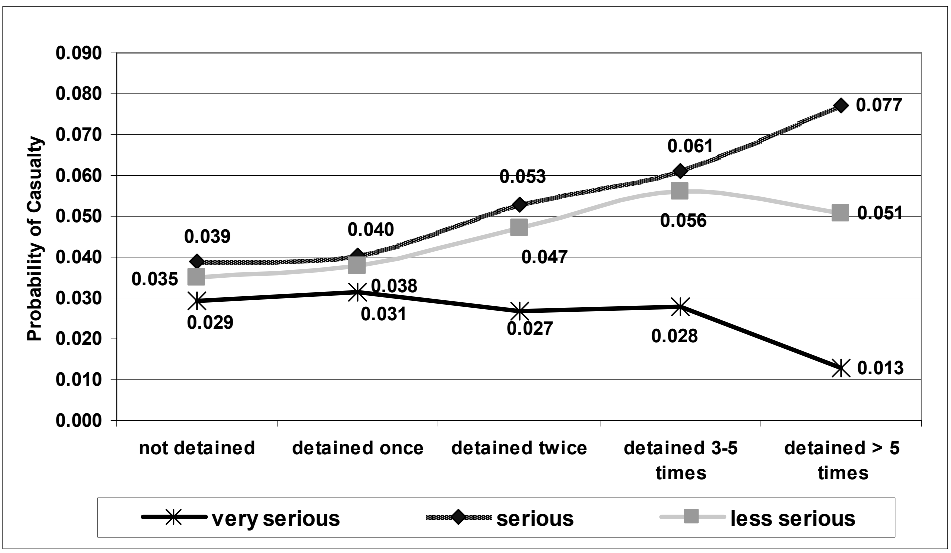
Figure 96 then shows the probability of casualty and how it changes with the frequency of detention versus not detained ships. The graph shows that for ships that are inspected and detained six months prior to a casualty, the probability decreases from an average of 2.9% to 1.3% for very serious casualties over a time period of six years while it increases for serious and less serious casualties. For less serious casualties, it then decreases again after the ship has been detained more than 3 times. The same applies for very serious casualties but not for serious casualties where the probability increases from 6.1% to 7.7% for ships that have been detained more then five times.

Figure 95: Probability of Casualty per Frequency of Inspection (6 months prior)



Note: based on a time frame of six years or 4 complete inspection years and average probabilities of approx. 50,000 vessels

Figure 96: Probability of Casualty per Frequency of Detention (6 months prior)



Based on casualty normal model and on average probabilities of approx. 50,000 vessels

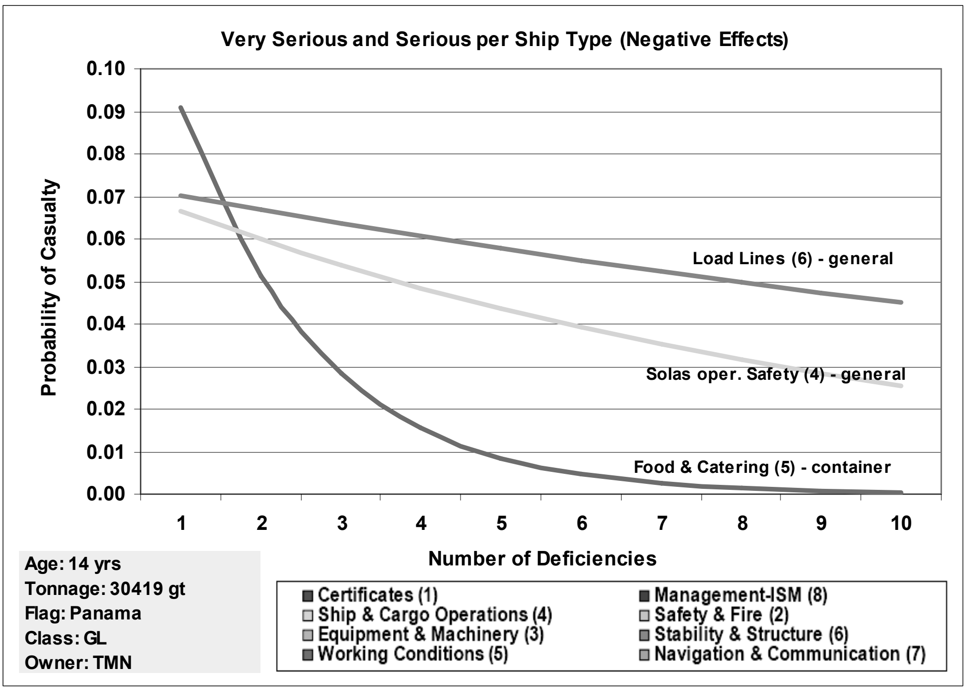
The fact that the probability of casualty for serious casualties and less serious casualties increases with either the frequency of inspection and detention could also indicate the involvement of a certain human factor associated with these casualties. It might be easier for port state control to identify very substandard vessels and therefore the effect of inspections and detentions are expected to be higher for very serious casualties while this is not the case for serious and less serious casualties. On the other hand, the increased probability of casualty for increased inspections and detentions also reflects to a certain extend that higher risk vessels are targeted for inspection. As third reflection, increased inspection or over inspection does not necessarily have a negative effect of the probability of detention. The last chapter of part III will give some more insight into deficiencies and the probability of casualty either by seriousness or casualty first event.

7.4.4. PSC Deficiencies and the Probability of Casualty

The last chapter of this thesis will provide a closer look at deficiencies in relation to seriousness and first events of a casualty and is based on the Type I, II and III models. It visualizes the findings stated in Table 48 previously in order to facilitate the interpretation of the coefficients.

The first set of graphs is 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 97 and Figure 98 show the results for codes with negative effects and codes with positive effects.

Figure 97: Very Serious and Serious Casualties (Negative Effects)



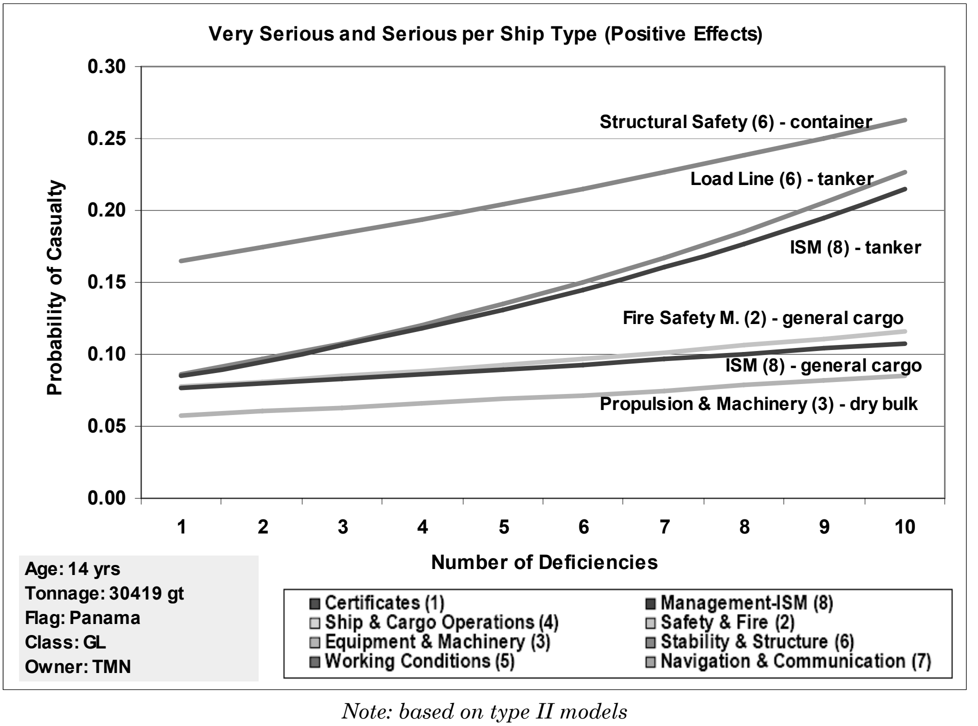
Note: based on type II models

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.

The significance of the other two codes for general cargo ships are easier to interpret. According to the Paris MoU Manual for PSC Officers[107] 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 98 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.

Figure 98: Very Serious and Serious Casualties (Positive Effects)



Note: based on type II models

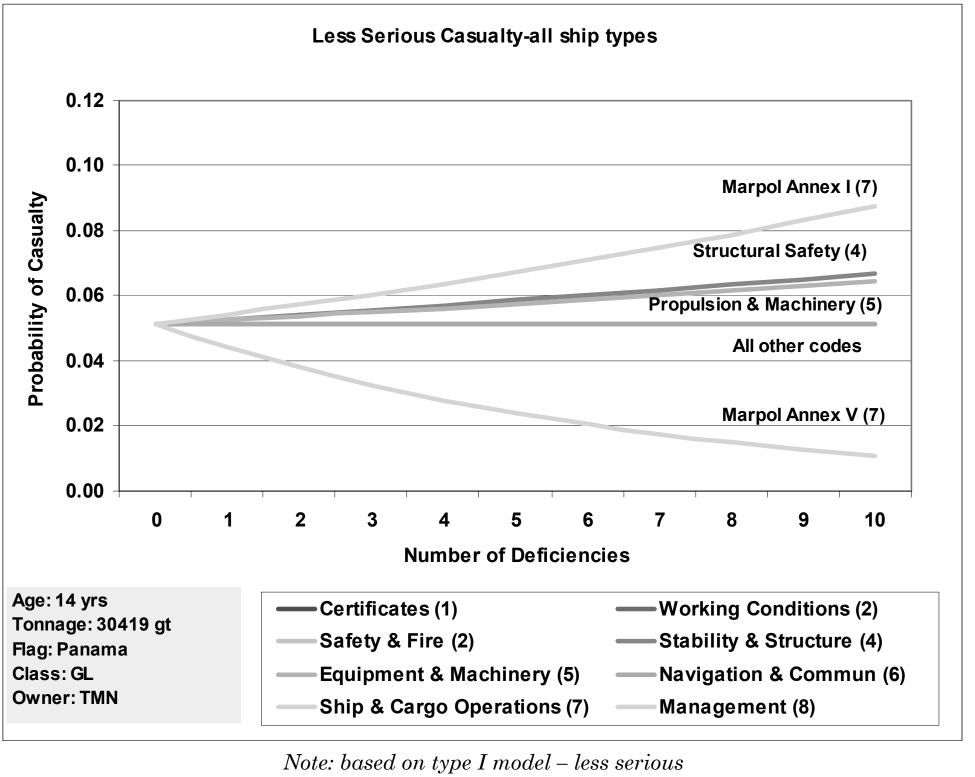
[107] Paris MoU, Manual for PSC Officers, Revision 8

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 48 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 99 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 99: Less Serious Casualties and Deficiencies



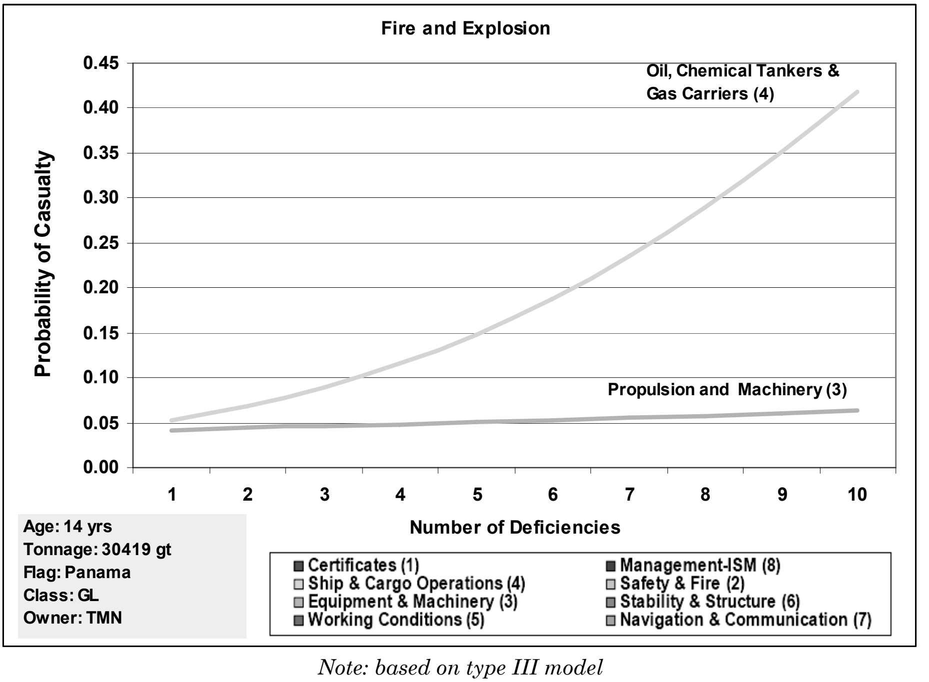
Note: based on type I model – less serious

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 100 through Figure 104. The deficiency codes are shown individually in the graphs and not in aggregated format such as the groups that were used for the visualization part of the probability of detention (see Table 23: Grouping of Deficiency Codes for Visualization) since few deficiency codes remain to be significant in the final models. It is therefore more accurate to show the codes individually. Nevertheless and to keep the coding across the models the same, each graph shows a legend at the bottom with the deficiency groups used for the probability of detention and the corresponding number (e.g. 4 for cargo and ship operations) links the actual code shown in the graph to the deficiency main groups of the probability of detention graphs produced in Part II of this thesis.

Figure 100 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.

Figure 100: Fire and Explosion and Deficiencies



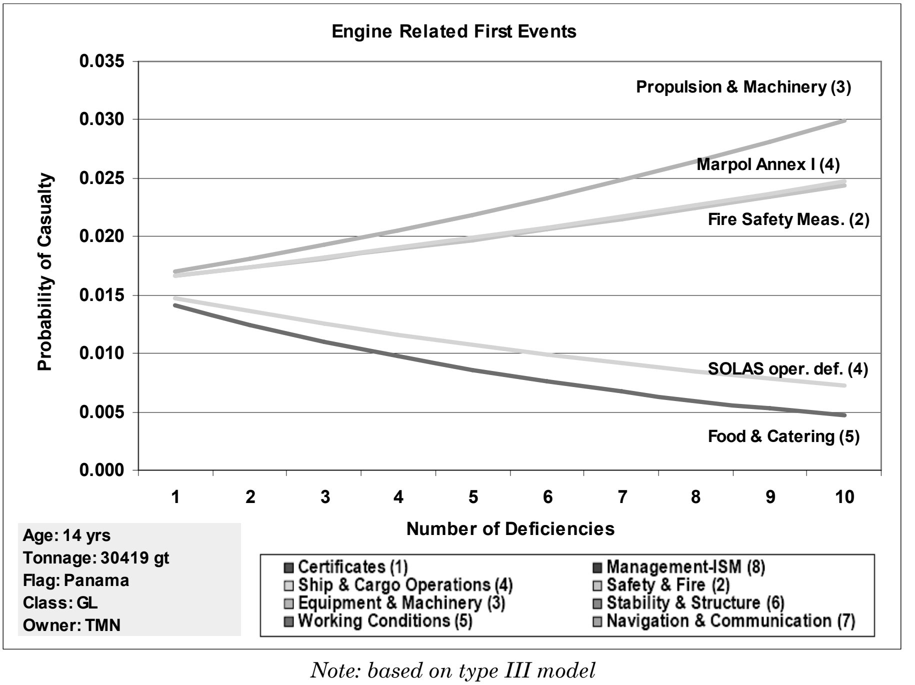
Note: based on type III model

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[108] (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.

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 98. 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 101 shows the probability of engine related first events and Figure 102 gives an insight into the probability of deck related first events in relation to deficiencies previously found in port state control inspections.

Figure 101: Engine Related First Events and Deficiencies



Note: based on type III model

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

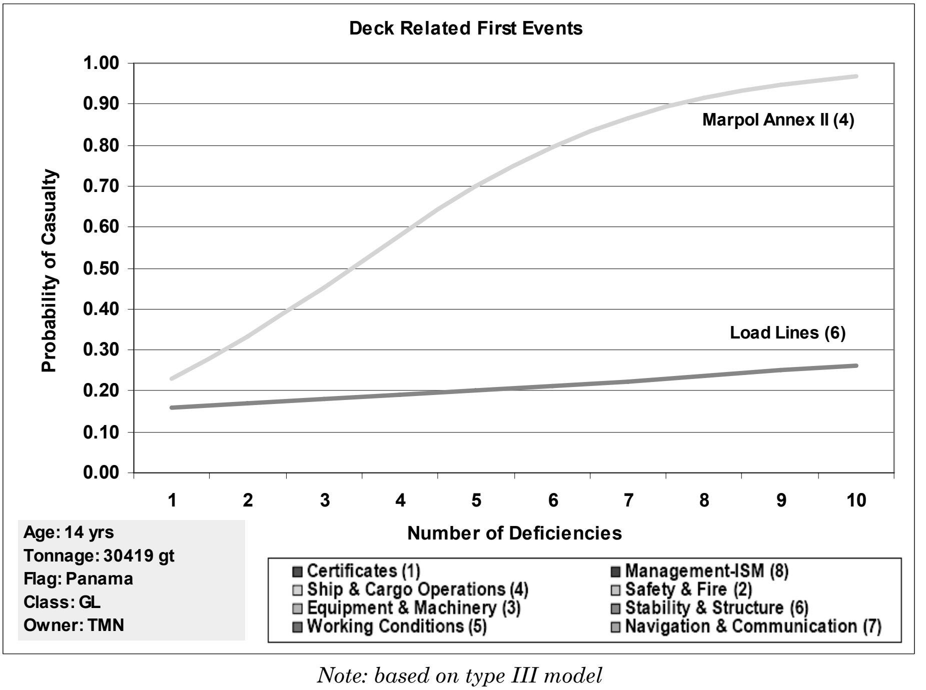
[108] Maritime Safety Committee Meeting at IMO (10th to 19th May 2006)

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.

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 102 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).

Figure 102: Deck Related First Events and Deficiencies



Note: based on type III model

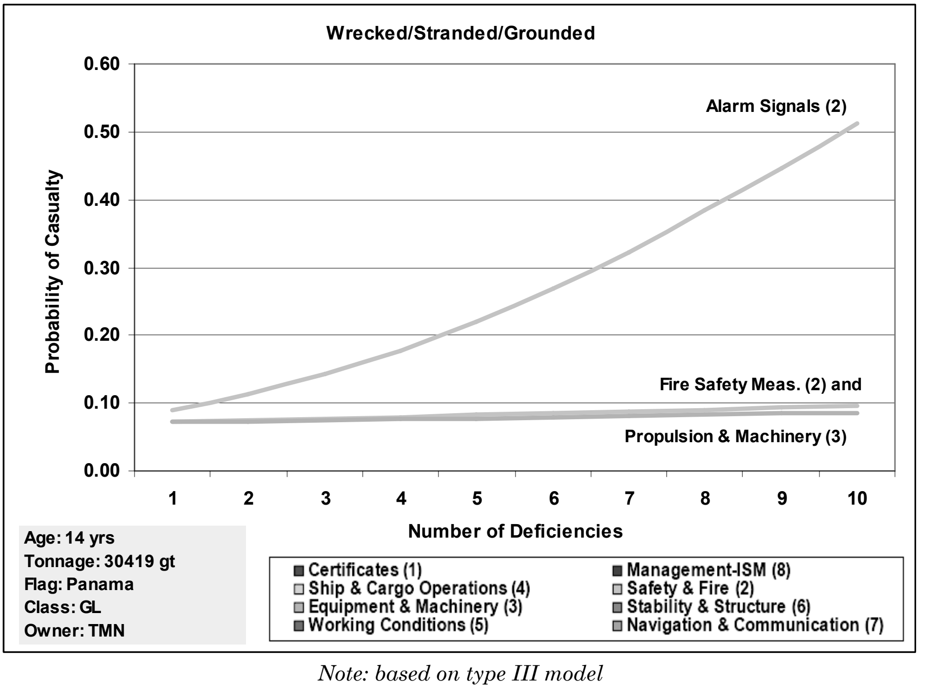
According to the Paris MoU PSC Manual for PSC Officers[109], deficiencies associated with MARPOL Annex II (Noxious Liquids in Bulk) are deficiencies such as the cargo record

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

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

Figure 103 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.

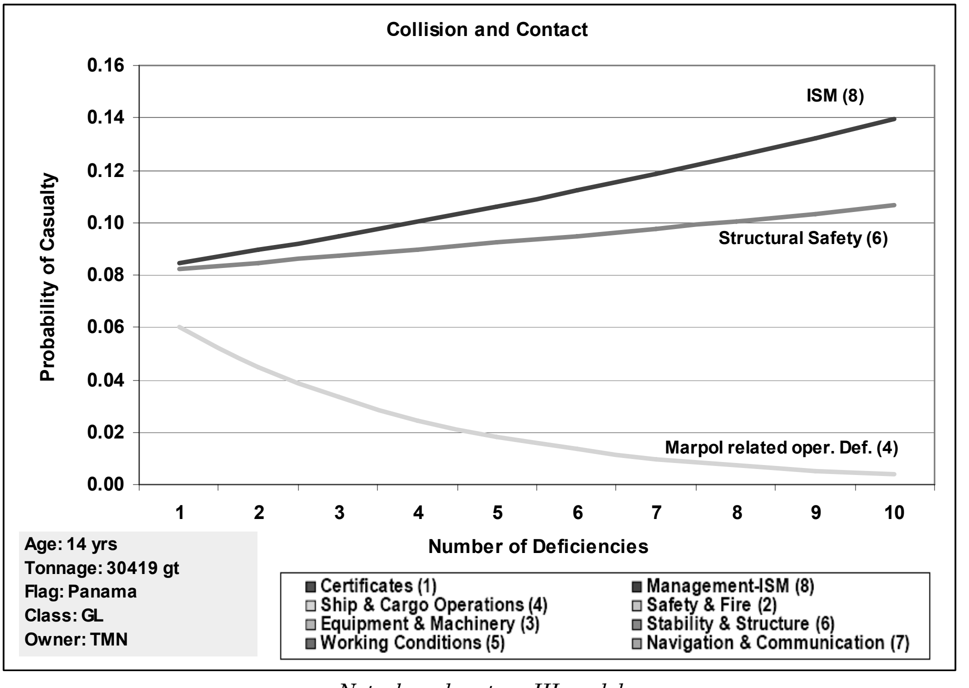
Figure 103: Wrecked/Stranded/Grounded and Deficiencies



Note: based on type III model

Figure 104 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 104: Collision and Contact 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.

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[110] 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[111]:

- *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 thesis, 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.

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.

7.5. Summary of Major Findings: 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.

[110] 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

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

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.

PART IV

This final chapter of the thesis will combine all the various aspects which have been looked at in this thesis in order to provide the answer to the research questions and to give recommendations. It therefore provides a condensed summary of the major findings and gives recommendations on how the safety regime can be improved. It will end with suggestions on further research in this area.

Chapter 8: Conclusions and Recommendations

The author would like to stress that this thesis is an independent study and should be understood as a first attempt to look at various aspects of inspections and their link to casualties and is by no means complete due to some barriers which could not be overcome for this study and access to some PSC data could not be obtained. The political dimension of flag state compliance and port state control is not treated by the author in this study but emphasis is given on the technical aspects of this topic only.

Before presenting the main findings and recommendation of this thesis, it is perhaps useful to re-state briefly the original research questions which are to be kept in mind: 1) What is the present state of the safety regime? 2) Can targeting of ships for inspections be improved? 3) What is the effect of inspections on casualties? and 4) How can inspections be improved? The areas of these questions are overlapping and are therefore not treated separately but in order to put some structure into this last chapter in addressing these questions, four overall sections were identified as follows: general overview of the safety regimes, the overall magnitude of improvement possibilities, the effects of inspections on casualties and recommendations on how to improve the target factor and finally, identified areas to improve inspections.

8.1. General Overview of the Safety Regime

Many players are part of the safety regime consisting of a statutory part and an industry driven part. The lack of trust in the industry between flag states, port states, classification societies, insurance companies and cargo owners has created a playground for many inspections which are performed on certain ship types (oil tankers, chemical tankers and dry bulk carriers) in the name of safety. The areas that are inspected in all of these inspections show a considerable amount of overlapping although the overall emphasis of industry driven inspections versus statutory inspections is different. The estimated inspection costs of a port state control inspection is USD 747 per inspection and port state control inspections associated with zero deficiencies (which accounted for 54% of all inspections of the dataset used) are estimated to be at USD 12.5 million per year for the regimes used in this study. The figures are not completely accurate as they do not take the differences of administrative costs of all countries present in this study into consideration. Total inspection costs of mandatory and non-mandatory inspections per vessel per year are estimated to vary from USD 47,000 for tankers to USD 17,500 for other ship types while the frequency of all inspections performed in the name of safety is estimated to be at 11 inspections per year for tankers, 6 for dry bulk carriers and 5 for all other ship types.

In addition, the inspection regimes do not accept each others inspections and in particular, port state control inspections that are performed in another regime are not taken into consideration by another port state control regime. The same applies for the industry driven inspections where no information is exchanged between the vetting inspection systems[112]. This leaves certain ship types to be exposed to a relatively large amount of inspections where the inspections are performed sometimes during critical port operations and increase the working hours of crew which further adds pressure and fatigue to the overall work load in ports due to shortened port stays. The underlying question is how the functioning of the safety regimes can be improved and how the money

[112] CDI and OCIMF

allocated to port state control (which is understood to be the second line of defense in eliminating substandard ships) can be better used.

One suggestion would be to improve the target factor of vessels by introducing a system which spans across the regimes and which also enhances cooperation between the port state control regimes. With the development of GISIS[113] as a centralized database of port state control data and casualty data, the combined data can provide a very useful and overall picture of vessels. In addition, comments on inspections from flag states can also be incorporated into the system and another group that could provide valuable feedback would be the classification societies.

The role of classification societies is disputed due to the conflict of interest and its split role of both public and commercial functions. Nevertheless and in particular with respect to the statutory functions that are performed by class on behalf of the flag states, their comments on inspections, and in particular follow up inspections of detained vessels can all be valuable sources of information. The reason for allowing flag states or classification societies to comment is to create a system that allows for follow up on inspections which is lacking in the industry.

The overall aim is to decrease inspections on complying vessels and to increase the frequency and time of inspections spent on substandard vessels in the areas where the inspections are needed most and show the best effect on decreasing the probability of a casualty. With respect to the casualty locations, high risk areas for the time frame 1999 to 2004 were West Africa, the Indian Ocean region, the North Atlantic East region and the South China Sea. Regardless of the political dimension of port state control and the underlying question of flag enforcement, increased cooperation in standardizing the inspection procedures and providing training to emerging regimes should further speed up the process. Developments into this direction are underway with the latest decisions made at FSI (14)[114] at IMO in June 2006.

In addition, about 47% of the world fleet is eligible for port a state control inspections which excludes the fishing fleet. Descriptive statistics show a high amount of casualties related to fishing vessels (approx. 7% of the world fleet). Incorporating the fishing fleet into the safety regimes in an adapted inspection version to port state control should enhance the safety culture onboard the fishing fleet and increase the overall safety level of this industry. Comparison between the probability of casualty based on a certain flag of the commercial fleet versus the fishing fleet has further shown that flag by itself is not the sole indicator of sub-standardness but that many other variables play a role.

An interesting finding which further quantifies the effect of the relevant legislative instruments on the probability of casualty is reflected by the result in relation to the number of legal instruments a flag state has ratified and the number of legal instruments a country of residence of the owner has ratified. While the first variable is significant for all types of casualties (very serious, serious and less serious), the latter is only significant for serious casualties. The associated effect is negative meaning that ratification has a decreasing effect on the probability of casualty. To a certain extent, this means that ratification has led to more enforcement and that this effect can be measured. On the other hand, some other results of the analysis provide evidence that more improvement

113 Global Integrated Shipping Information System (IMO)

114 During FSI 14 (Flag State Implementation Sub-Committee meeting in June 2006, steps to harmonize port state control have been indentified and a working group has been established to deal with all PSC related issues in the future.

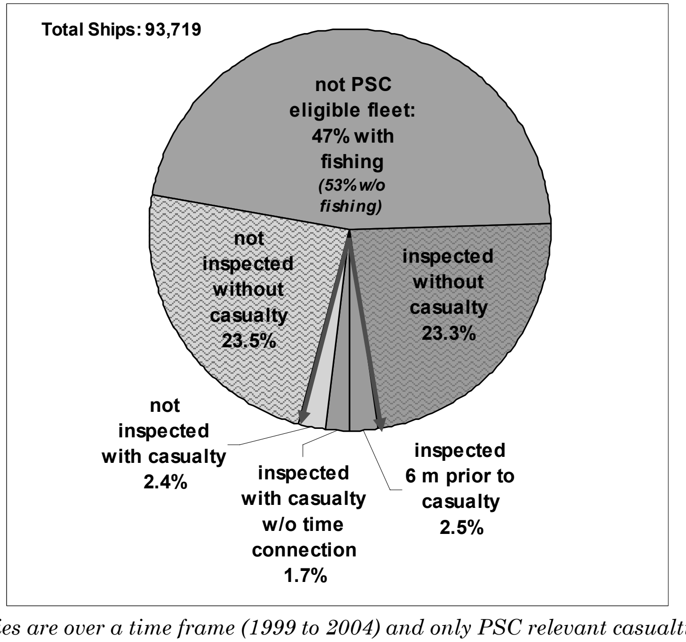
can be achieved. It will be interesting to see how the implementation of the IMO Voluntary Member State Audit will enhance implementation of the conventions.

8.2. The Overall Magnitude for Improvement Possibilities

The variables which are used by the port state control regimes to target vessels for inspection are similar variables that were used in the regressions to determine the probability of detention and the probability of casualty. It can be confirmed, that the classic variables such as ship type and size, age, flag, classification societies, the number of deficiencies previously found in an inspection are all relevant and valid variables to be used to target vessels for inspections. What remains to be seen, is how targeting can be improved. First, an overall view of the picture will be presented and then the main findings based on the probabilities will be shown.

To provide an overall view of the picture on inspections and casualties, Figure 105 shows the amount of ships that were exposed to inspections and how they relate to casualties.

Figure 105: The Overall View on Inspections and Casualties (1999 to 2004)



Note: Casualties are over a time frame (1999 to 2004) and only PSC relevant casualties are shown in this graph plus the fishing fleet (>400gt)

The fishing vessels (>400gt) of which the casualties are also considered are also incorporated into this figure. The graph gives an overview of the total fleet where the portion on top shows the portion not exposed to port state control minus a portion of the fishing fleet (above 400gt) which is also considered in this study. The right hand lower part of the graph represents inspected ships and the left hand side of the graph represents ships that have not been inspected by the respective regimes[115] or not inspected at all. The lower middle portion summarizes the vessels that had casualties.

One can see that about an equal amount of ships that had not been inspected by the regimes in question (they might have been inspected by another regime only) did not have a casualty – about 46% of the world fleet including fishing vessels above 400gt. Not inspected ships with casualties accounted for 2.4% of the world fleet versus 1.7% of the vessels which had a casualty and were inspected without any related time frame and 2.5% of the vessels were inspected six months prior to a casualty.

What is interesting to notice but which is not shown in this graph is that based on the individual port state control inspections, 54% of all inspections were inspections with zero deficiencies while when aggregated by ship and taken as a summary of all inspections performed on vessels, this percentage reduces to 16% of all inspections for the time frame 1999 to 2004. On the other hand, if only looking at the last inspection six months prior to a casualty as shown in the figure with 2.5% of the total world fleet, 52.3% of these vessels were ships with zero deficiencies.

It is difficult to give a conclusion on the target factor based on the percentages above. The portion of ships which have been inspected can be understood as the ships that have been targeted for inspections of which a certain portion was assumed to be sub-standard. About 16% of all inspected vessels had zero deficiencies over the time period in question and these ships might have been ships which should not have been targeted (4,221 ships). On the other hand, looking at ships which have been inspected six months prior to a casualty (2,321 ships) where 52.3% of these vessels had zero deficiencies (1,215 ships) and the rest had deficiencies. This changes the 4,221 ships which should not have been targeted into 3,006 vessels or approx. 501 ships per year.

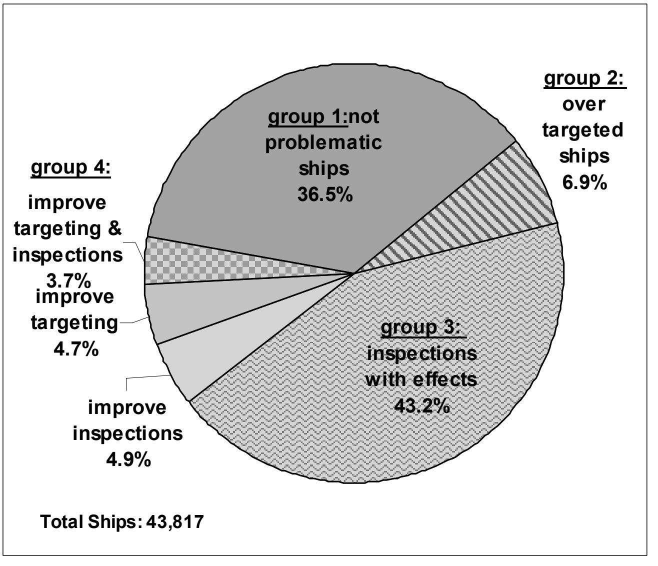
It is further worth noticing that out of the 1,106 vessels (2,321 – 1,215) with deficiencies, 14.6% were detained (162 vessels) and had a casualty. The mean amounts of deficiencies of these vessels are by 4.3 deficiencies for black listed flag states versus 2.7 deficiencies for grey and 1.7 deficiencies for white listed flag states. Per seriousness of casualty, detained vessels show significantly higher amount of deficiencies. This portion could be understood as ships that have been targeted correctly and identified as sub-standard vessels but for some reason, detention was not sufficient to increase the safety standard of the vessel to prevent a casualty. The remaining portion of the vessels which have been inspected and were deficiencies were found are the vessels where the effect of inspections decreased the probability of a casualty which is the partial effect of the regressions in part III of this thesis. In number of vessels, this amounts to approx. 18,874[116] vessels or 3,146 ships per year. The left side of Figure 105 shows then the not inspected portion of which 2.4% of the vessels had a casualty. In number of ships, this accounts for 2,213 vessels or approx. 369 ships per year. This is an area of improvement for targeting.

Figure 106 then visualizes the discussion above and presents a summary of the magnitude of possible improvement areas for port state control. The figure is only based on ships that are relevant for port state control (excluding the fishing fleet > 400gt) and is a summary of the total time frame. The graph shows several groups out of which *group 1* of about 36% of the vessels eligible for inspections are identified not to have been

[115] As explained previously, some Port State Control regimes decided not to participate in this study such as the Tokyo MoU, the Black Sea MoU or the Mediterranean MoU while others did not have any data available yet.
[116] 21,880 total inspected ships with no casualty minus 3,006 ships with no deficiencies

problematic over the time period and have also not been targeted by the regimes in question. About 7% of the vessels eligible for port state control have been targeted over the time frame but did not have a casualty and also no deficiencies and therefore represent a group of over-inspected vessels *(group 2)*.

Figure 106: Improvement Areas for PSC eligible ships (1999-2004)



Note: Based on only PSC relevant ships and based on total time frame (1999-2004)

Group 3 consists of 43% of the vessels that can be identified to belong to a group where inspections are effective in decreasing the probability of casualty where this effect is strongest for very serious casualties and estimated (depending on the basic ship risk profile) to be a 5% decrease per inspection. This category can also represent further room for improvement but shows that port state control is effective.

Group 4 is split into three portions. The first portion is 4.9% of PSC eligible vessels which are the amount of ships that have been targeted correctly but since they had a casualty within six month after the inspection, the enforcement could be improved. The second portion shows 4.7% of ships which had a casualty but were not inspected and where targeting could be improved. Finally, the last category shows a grey area. In this group, ships had a casualty but regardless of the time frame. Therefore, inspections and possibly targeting could be improved. Most improvement to decrease the probability of a casualty can be achieved by concentrating on the categories in group 4 by shifting the emphasis from group 2 to group 4.

Taking the probabilities of casualty into account, the probability of casualty changes per ship type and confirms that general cargo vessels are ships with the highest probability of a casualty which is confirmed by the probability of detention. Black listed flag states or non inspected ships show a higher probability of a very serious casualty compared to grey and white listed flag states while the same does not hold for serious and less serious casualties. It confirms that the target factors are targeting high risk vessels but are less effective in decreasing the probability of a serious and less serious casualty.

Overall, one can identify areas for improvement of either the targeting of sub-standard ships or the inspections itself. The next chapter will give recommendations on how to improve the target factor but will also summarize the effects of inspections on the probability of casualty before the last chapter will give recommendations on how to improve the inspections.

8.3. Effect of Inspections and Improvement for Targeting

One could argue that port state control works best as a regional agreement. The basic ship profiles given by age, size, flag, class and ownership do not vary significantly across the regimes with respect to the probability of detention. Most differences across the regimes with respect to the probability of detention can be found within the use of the deficiency codes towards detention and the port states. When combined by ship types, the differences average out but looking at the ship types individually, one can see that certain codes show higher contributions compared to each other within each of the regimes.

The basic ship risk profile based on the probability of detention (without taking the effect of deficiencies into account) for all regimes is between 0.5% to 1.5% while the basic risk profile based on the probability of casualty reveals that the average probabilities of a casualty are by 0.06% (very serious), 1.6% (serious) and 1% (less serious) respectively. With reference to ship types, general cargo vessels seem to show the highest probability of a very serious and serious casualty of 1% and 2% respectively followed by passenger vessels for very serious casualties. Tankers and container vessels are below 0.5% for very serious casualties and 1% for serious casualties. Container vessels show the lowest risk in all three types of casualties. Comparing ships that have been inspected with ships that have not been inspected by the respective regimes, the strongest difference can be seen with general cargo vessels and dry bulk carriers for very serious casualties and least of the effect can be seen with tankers and container vessels which is not surprisingly for tankers due to the amount of vetting inspections that are performed on oil and chemical tankers.

With respect to average insurance claims, tankers and passenger vessels show the highest average claim amount while general cargo and containers show the lowest for the time period 1999 to 2004. The probability itself describes the risk associated with a particular ship type and for very serious casualties, this means loss of life, complete loss of the vessel or substantial pollution. According to the claim costs above the deductible, tankers still remain a high risk vessel due to the higher costs associated with a casualty despite the fact that the probability is rather low. One can further see a significant difference between insurance claim figures of port state control inspected vessels versus not inspected vessels and that the difference is in particular significant for tankers and passenger vessels. In addition, the regressions of the probability of casualty has shown that some parameters of the variables used in the analysis show a positive effect towards the probability of a very serious, serious or less serious casualty, some show a negative effect and some are not significant.

If a ship changed its classification society during its course of life, the partial effect is negative on the probability of casualty for all casualty types. This could mean that in general, if a class is changed, an inspection is performed which might have a positive influence on the quality of the vessel. On the other hand, a ship whose class is withdrawn shows a higher probability of all types of casualties. Both variables can relatively easy be incorporated into the targeting matrixes of port state control regimes. With respect to classification societies, the probability of a casualty for Non-IACS class is higher than for IACS class and is also confirmed by the probability of detention.

On the other hand, change of flag does not seem to be significant while change of ownership shows a strong positive effect towards the probability of casualty for all types. This could indicate a change of a vessel into second hand ownership or into a segment of the market where less money is spent on safety. Again, this information besides the actual information to incorporate the beneficial owner or DoC[117] Company into a targeting matrix for inspection can easily be obtained and incorporated. For ownership groups and in comparison of inspected to non–inspected vessels, highest probability of casualty lies within owners from open registry countries followed by unknown owners, owners from traditional maritime nations and emerging maritime nations. This does not follow the probability of detention where owners from traditional maritime nations show the lowest probability of detention.

The coefficient for the variable double hull is not significant for any type of casualty. Some classification societies, flag states, ownership groups and ship yard countries remain to be significant with either a positive or negative effect on the probability of casualty. Age only remains significant for very serious casualties and as the age of the vessel increases, the probability of having a very serious casualty increases by about 12% over a 35 year period which translates into about 0.35% per year. Tonnage is also only relevant for very serious casualties but is negative indicating that a smaller vessel seems to be at higher risk than larger vessels which goes in line with the general cargo vessels being more high risk prone.

Easily incorporated into the target factor can be a variable indicating if a ship has been Greenaward certified or inspected by Rightship. Although partial effects for Greenaward certified ships cannot be measured which might be due to lack of data, the average probabilities of a very serious casualty is clearly lower than for non certified vessels. Based on the inspection data, the mean amount of deficiencies is lower for Greenaward certified vessels than for non certified vessels. As for ships inspected by Rightship, the partial effect can be measured and the star ranking can be confirmed.

The parameter for detention is not significant towards the probability of casualty but inspections are. The fact that it is not significant and not negative (as expected) shows that its effect cannot be measured and might be overruled by the effect of inspections in general since only very few vessels are detained within a certain time frame and prior to a casualty (162 vessel). In addition and based on average probabilities, the probability of casualty increases by 0.1% as the number of deficiencies increases. This is irregardless of the time frame of the inspection and is based on the total inspection time frame of about six years.

The parameter obtained for the variable indicating the time span in-between inspections 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. Time span might therefore be important to further improve the efficiency of port state control with respect to serious and less serious casualties.

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[117] Document of Compliance Company (the company which is according to ISM, the responsible company for the safety management onboard a vessel)

Overall, one can conclude that the classic variables such as ship type, age, size, flag, the classification society, deficiencies found in prior inspections and detention are all valid variables for targeting sub-standard ships for inspections. However, the targeting of ships can further be improved in order to capture a certain amount of vessels which are not inspected but have a casualty. Improvement can be made by adding the variable indicating the ownership of a vessel and certain data on ship history such as change of class, class withdrawal and change of ownership.

Another possibility would be to include where the ship was built and if possible, if a ship had undergone vetting inspections. The ship profile can change over time and targeting factor therefore needs to be dynamic and adaptable from time to time. At first sight, it seems that too many ships with zero deficiencies are targeted but when aggregated by ship over the whole time period, the percentage of ships with zero deficiencies reduces significantly but a certain group of vessels which are over-inspected are still identified and efforts to inspect those vessels should be shifted towards the group 4 identified in Figure 106.

Targeting on combined data as described in the previous chapter by making inspections available to all regimes can further enhance the overall targeting and concentrate on high risk vessels versus ships that comply. It allows gaining a better picture of a vessel inspection history over time and can help to identify sub-standard vessels, even if there are differences in the inspections which were confirmed by the probability of detention and the parameters that were obtained for the deficiency codes and the port states. It can also help in identifying if performances of flag or classification societies vary significantly across the globe which this study in its results cannot support as no significant difference with respect to the probability of detention could be identified in part II of this thesis.

8.4. Identified Areas for Improvement of Inspections

The last area will summarize the findings with respect to deficiencies for either the probability of detention or casualty which could be identified in Figure 106 since some ships are targeted correctly for inspections but the effect of the inspection cannot be measured as being effective enough. The two groups of casualties are primarily serious and less serious casualties where serious casualties are seen to be more relevant for port state control.

The probability of detention models revealed the highest contribution of deficiencies in the areas of certificates, ship and cargo operations, the ISM[118] code and safety & fire appliances while lowest contribution is found for machinery and equipment. The probability of casualty either per seriousness of casualty or casualty first event also revealed three areas of interest – *the ISM code, ship and cargo operations and machinery and equipment*. Those are the main areas which have been identified were room for improvement exists.

What is interesting to notice is the relative high contribution of *ISM related deficiencies* for some ship types and regimes for the probability of detention and the positive effect of ISM related deficiencies towards the probability of casualty. 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,

[118] International Safety Manamagent Code

accidents and near misses, the maintenance of the vessel and company audits. Another area deals with resources and personnel. Its effect is positive for very serious and serious casualties on general cargo vessels and tankers and for casualty first event collision and contact. 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 is not very successful. Besides ISM, structural safety also shows a positive effect for very serious and serious casualties on container vessels and for less serious casualties on all vessels. This could further reflect poor implementation of maintenance programs which are part of the ISM system.

The author can fully support the recommendations given in MSC 81/17/1 which includes a more systematic training, increase monitoring of compliance as well as involving seafarers into the development of ISM manuals. In addition, Argentina presented at the last Sub Committee on Flag State Implementation (FSI 14)[119] in June 2006 a proposed IMO model course for training of ISM auditors and has established an inter-sessional group to further develop the course. The author finds that such model course should also be made available to port state control officers in the future for additional training. Lack of recognition by port state control does not seem to be the real problem. The improvement with respect to decreasing the probability of casualty would be by improving enforcement of the code. More detailed audits should be requested and information should be made available to flag state and recognized societies for all inspections and deficiencies related to ISM and not only detentions. In addition, further research in this area especially with reference to audits performed by recognized organizations and on DoC companies can be beneficial in this respect. With this respect, the revision of the port state control deficiencies is a very welcoming development which will hopefully in the future allow better analysis in this area.

While ISM is more related to the system's side of the safety management onboard a vessel, deficiencies in the area of ship and cargo operations include all the relevant operational aspects of the ISM code. For the probability of detention, *ship and cargo operations* seem to be more important for tankers while the effect of deficiencies of stability and structure are highest for dry bulk carriers and containers. With respect to the probability of casualty, this group of codes can vary considerably. Negative effects can be found with code 2000 (SOLAS operational related deficiencies) for general cargo ships and for engine related first events for all ship types as well as with code 2300 (MARPOL Annex V: Garbage) for less serious casualties and with code 2100 (MARPOL related operational deficiencies) for first events collision & contact – again for all ship types. On the other hand, positive effects can be found with code 1700 (MARPOL Annex I: Oil Pollution) for less serious casualties and engine related first events, code 1800 (oil, chemical tankers & gas carriers) for first event fire & explosion and with code 1900 (MARPOL Annex II: Noxious Liquids) for deck related first events.

If the effect is negative, effective implementation and rectification can be found on board such as deficiencies in the area of code 2000 which also includes drills. Therefore, in shifting the emphasis of inspections from over-inspected ships to more substandard ships, inspections could be expanded to include drills also which is for instance the case with the USCG but is not done on a regular basis in other regimes. Rooms for improvement can also be found in rectifying or following up deficiencies in the area of MARPOL Annex I, code 1800 (oil, chemical tankers & gas carriers) and in the area of MARPOL Annex II. As for fire and explosions on chemical tankers, the area has already been identified and been

[119] FSI 14/3/1, agenda item 3, Evaluation of model training courses, Model Course: Safety Management System Auditor (ISM Code), 21 February 2006

dealt with during 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 human error by not following the proper procedures which is also reflected in the positive contribution of the ISM related deficiencies for tankers.

Linking this with the findings of the probability of detention, one could further conclude that there is room for improvement in the area of ISM related deficiencies as well as in the area of ship and cargo related deficiencies and in particular, the proper implementation of procedures onboard as well as the follow up by flag states, recognized organizations who perform ISM audits and the DoC companies. Port state control can further improve the system by making information available to all inspectors.

The last identified area for improvement for inspections is machinery related items such as propulsion and aux. engines. In this area, lowest contribution towards the probability of detention is found for the deficiency codes associated with machinery and equipment while about 32% of all port state control relevant casualties between 1999 to 2004 show signs of a casualty first event in engine related areas. With respect to the probability of casualty, Code 1400 (propulsion & aux. engine) 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 or grounded and engine related casualty first events. On could argue that it is not easy to find deficiencies in this area during port state control inspections since during port time, the engine is not up and running. However, it seems that deficiencies are found which might indicate a possible problem but due to limited testing possibilities in port and possibly due to lack of enforcement or follow up on deficiencies, the effect of such deficiencies is positive rather than negative towards the probability of casualty.

For casualty first event wrecked, stranded or grounded, code 1000 (alarm signal) shows a relative strong positive effect on the probability of having a casualty. With respect to the probability of detention, the deficiency group navigation and communication which includes code 1500 but also code 1600 show the highest variety across the regimes while the deficiency group safety & fire which includes the alarms does not vary much across the regimes. A simple recommendation can be to perform a concentrated inspection campaign on this topic to see if there is any other latent problem.

As a last word of recommendation, the author feels that emphasis on working and living conditions including working and rest hours onboard vessels should be increased. While the only group of codes related to this group of deficiencies is code 400 (food and catering), the parameter of this code shows a negative effect on the probability of a very serious casualty as well as towards the probability of an engine related first event. This study did not concentrate on the human element but can support any development in this area. The effect of inspections is only negative for very serious casualties and slightly positive or none existing for serious and less serious casualties and a higher portion of human related errors are associated with them which are more difficult to detect through port state control normal practices. The same applies for vetting inspections.

8.5. Suggestions for Further Research

In organizing this project and writing this thesis, the author came across several barriers which could not be eliminated but provided an opportunity for new ideas to conduct research in the future.

One of the difficulties which provided limitations to this study was the inability to obtain data from some of the port state control regimes, namely the Tokyo MoU, the Black Sea MoU and the Mediterranean MoU. A very valid suggestion for future research which can easily be done through GISIS[120] is to include port state control data from all regimes which will further refine the findings of part III of this thesis. Another barrier to this study was the inability to obtain data from two of the vetting inspection regimes, namely CDI and OCIMF. Future research in this area could be the incorporation of this data and relate it to port state control data.

A further refinement to the analysis could be to split up the variable indicating the classification society into their respective areas of responsibility onboard since a vessel can have up to three different classification societies. By doing so, a more refined view on the performance of classification societies can be obtained. While this information might not be possible to receive for all casualty data, it is available for port state control data. With respect to change of class, one could further indicate whether the change was between two IACS class member or not.

With this in mind, ISM audit reports and timings or time elapsed between inspections and annual or periodical surveys could also be incorporated into the analysis in order to obtain the effect of the timings of the surveys performed onboard. Finally, a separate analysis can be performed based on data from classification societies which provides more detailed information then port state control inspection data. Any future research should try to measure the actual impact of ISM on the probability of casualty. This study could not provide a negative relationship – on the contrary, it has shown that there is lack of implementation and enforcement of ISM in the industry.

With respect to ship types and if the amount of data can be increased, separate regressions could be performed per ship type and seriousness or casualty first events which will further refine the results, especially with respect to the deficiency codes. A separate analysis for all passenger vessels including smaller ferries and fishing vessel including smaller ships (below 400gt) could also be performed in the future to obtain a better view of these two areas since both ship types are of special interest.

Finally, one could use duration models based on a more extended time frame and look into changes of probabilities over time for either the probability of detention or the probability of casualty. Another area would be to find the optimum global targeting factor while allowing for some regional differences. Ideally, the target factor would be constructed on combined data and would take a vessel's history into account where maybe changes in probabilities are also considered. The optimum amount of inspections could also be a further topic of interest.

In the area of port state control, further research in order to try harmonizing port state control procedures, the impact of an inspector background of cultural surroundings would be beneficial to bring some more insight into this area. While this study has tried to look at it briefly and could identify some differences with respect to the probability of detention, it did not provide a detailed insight into the background of inspectors across regimes. The same could be performed for vetting inspectors or class surveyors with the respective datasets. Furthermore, with increased amount of data such as casualties and inspections over a longer time period, deficiency codes could further be broken down into the sub-codes. In addition, more research could be conducted with respect to follow up

[120] Global Integrated Shipping Information System (IMO)

actions to see how harmonization can benefit the follow up on inspections and decrease the probability of casualty.

Last, not least but not minder important, more research should be conducted which takes the human factor into account which should be possible once the correct type of data is available.

Summary in Dutch (Nederlandse Samenvatting)

Dit proefschrift moet gezien en begrepen worden als een eerste poging om te kijken naar port state control (PSC) op mondiale schaal door het effect te meten van inspecties op de waarschijnlijkheid van ongelukken en door gebieden voor verbetering te onderkennen. Wat nieuw is in dit proefschrift is de combinatie van PSC-gegevens van verschillende regimes en gegevens van ongelukken afkomstig uit drie verschillende bronnen in dezelfde tijdsspanne. De corresponderende onderzoeksvragen zijn: 1) Wat is de huidige toestand van het veiligheidsregime? 2) Kan de selectie voor inspectie verbeterd worden? 3) Wat is het effect van inspecties op ongevallen? 4) Hoe kunnen inspecties verbeterd worden? Het onderzoek is gebaseerd op ongeveer 183.000 PSC inspecties en 11.000 ongevallen tussen 1999 en 2004. Het zal hopelijk tot een nieuw hoofdstuk leiden in het onderzoek op het gebied van maritieme veiligheid. Maritieme veiligheid waarvan de toekomstige mogelijkheden, wanneer politieke barrières zijn geslecht en meer transparantie geaccepteerd is, niet genegeerd zouden moeten worden door zowel de bedrijfssector als de regulerende instanties. Verscheidene econometrische technieken worden gebruikt om een kansberekening van aanhouding en ongelukken te maken naar ernst of "eerste incident" - ongevallen. De auteur kijkt niet naar politieke dimensie van vlagstaat-implementatie of PSC maar concentreert zich alleen op de technische aspecten van het onderwerp in kwestie.

De maritieme sector wordt gekenmerkt door een uitgebreid juridisch kader gebaseerd op internationale wetten die beperkte wettelijke bevoegdheden voor handhaving bieden in geval van overtreding. Dit creëert mazen in de regelgeving en concurrentievervalsing door het bestaan van een markt met inferieure schepen. Vanuit publiek oogpunt gezien, is de gewenste situatie er één waarbij veilig en milieuvriendelijk vervoer en vermindering van het aantal inferieure schepen gestimuleerd wordt. Vlagstaten moeten worden beschouwd als de eerste verdedigingslinie bij het elimineren van inferieure schepen, gevolgd door de tweede verdedigingslinie, de havenstaten. Het gebrek aan vertrouwen in de sector heeft speelruimte gecreëerd voor inspecties van bepaalde scheepstypen inclusief een aanzienlijke hoeveelheid door de sector geëntameerde inspecties, waarin het totaal aan inspecties geschat wordt op 11 inspecties per jaar voor tankschepen, 6 voor droge-bulk schepen en 5 voor alle andere scheepstypen.

Twee gebieden waarin mogelijk een verbeteringsslag kan worden gemaakt zijn onderkend: 1) de selectie van inspecties en 2) de inspecties en het opvolgen van gebreken. Op het eerste gezicht lijkt het dat teveel schepen met nul gebreken worden uitgekozen maar na samenvoeging van schepen en regimes, neemt het percentage schepen met nul gebreken aanzienlijk af over de gegeven tijdsperiode. Desondanks is bij een bepaalde groep schepen (ongeveer 7 % van schepen die voor PSC in aanmerking komen) onderkend dat deze teveel geïnspecteerd worden, en zullen er pogingen moeten worden ondernomen om inspectie inspanningen te verschuiven naar de groepen van schepen die baat hebben bij een inspectie. Dit wordt geschat op ongeveer 14 % van alle schepen die voor PSC in aanmerking komen gebaseerd op de tijdsperiode die gebruikt is voor deze analyse. Het effect van PSC-inspecties op de kans op ongevallen kan gemeten worden voor "zeer ernstige" ongevallen maar niet voor "ernstige" en "minder ernstige" ongevallen. Afhankelijk van het algehele risicoprofiel van een schip, kan een inspectie de kans op een "zeer ernstig ongeval" mogelijk met ongeveer 5 % per inspectie verminderen, waarbij het effect zelfs 10 % kan zijn voor schepen met een hoge risicofactor.

Hoewel de sleutelgetallen over tekortkomingen en aanhoudingen variëren per regime, worden de verschillen in de kans op aanhouding alleen maar weerspiegeld in de verschillen in havenstaten en de behandeling van tekortkomingen en niet noodzakelijkerwijs door ouderdom, grootte, vlag, klasse of eigenaar. De selectiefactor kan verbeterd worden door ontwikkeling van een factor die gebaseerd is op gecombineerde inspectie datasets die rekening houden met de gehele inspectie geschiedenis van schepen en door rekening te houden met regionale verschillen. In de periode van 1999 tot 2004 werden West Afrika, het gebied rond de Indische Oceaan, het oostelijk deel van het Noord-Atlantische gebied en de Zuid-Chinese Zee, aangemerkt als gebieden met een hoog risico. Het verschil in het effect van inspecties op de kans op "ongevallen naar ernst" of "eerste incident"- ongevallen bevestigt bovendien een verschuiving van inferieure schepen van gebieden zoals het Paris MoU en de USCG naar andere gebieden van de wereld, zoals het Zuid-Amerikaanse gebied, het gebied rond de Indische Oceaan of Australië. Inspecties van deze gebieden blijken de kans op een ongeval te doen afnemen bij een significantie niveau van 1%.

De klassieke variabelen zoals scheepstype, leeftijd, grootte, vlag, de classificatie-indeling, tekortkomingen gevonden in eerdere inspecties en aanhoudingen zijn allemaal geldige variabelen voor het doelbewust selecteren van inferieure schepen. Vlag is maar een variabele uit de vele die kunnen worden gebruikt voor de selectie op inferieure schepen. Leeftijd blijft alleen significant voor "zeer ernstige" ongevallen. Naarmate het schip ouder wordt, stijgt de kans op een "zeer ernstig" ongeval met ongeveer 12 % over een periode van 35 jaar, hetgeen zich vertaalt in ongeveer 0.35% per jaar. De waarschijnlijkheid van een ongeval bevestigt bovendien dat general-cargo schepen, schepen zijn met de hoogste kans op een ongeval, hetgeen tevens bevestigd wordt door de kans op aanhouding. Vlagstaten op de zwarte lijst of niet geïnspecteerde schepen laten een hogere kans zien op een "zeer ernstig" ongeval in vergelijking met de vlagstaten op de grijze en witte lijst. Dit geldt niet voor "ernstige" en "minder ernstige" ongevallen. Daarentegen wijzen de gemiddelde kosten van een verzekeringsclaim uit dat de hoogste claimkosten gerelateerd zijn aan tank- en passagiersschepen

Verdere verbeteringen voor de selectie van inferieure schepen kunnen gemaakt worden door het toevoegen van de variabele die het eigendom of "DoC bedrijf"[121] van een schip weergeeft en specifieke data van de geschiedenis van een schip zoals verandering of intrekking van classificatie, verandering van eigenaar over een zekere periode of de locatie waar een schip gebouwd is. Al deze variabelen hebben een negatief of positief effect op de kans op een ongeval. Een andere mogelijkheid zou zijn om een variabele toe te voegen die aangeeft of het schip geïnspecteerd is door één van de vetting inspectie regimes (in geval van droge bulk) of gecertificeerd is door de Greenaward Foundation.

Nauwkeuriger onderzoek van de effectiviteit van inspecties wijst uit dat aanhoudingen niet significant lijken te zijn voor de kans op een ongeval, hetgeen een verassend resultaat is. Dit betekent niet persé dat een aanhouding irrelevant is, maar eerder dat misschien de inspectie zelf het effect met zich meebrengt. Tevens is de tijdspanne tussen inspecties niet significant voor "zeer ernstige" ongevallen maar wel voor "minder ernstige" en "ernstige" ongevallen. Gemiddeld en onafhankelijk van de ernst van het ongeluk stijgt de kans binnen een jaar met 2,3%.

[121] "Document of Compliance Company", is het aangewezen bedrijf dat verantwoordelijk is voor veiligheidsmanagement aan boord van schepen aan de hand van de "International Safety Management Code (ISM)"

Het risicoprofiel van schepen over alle regimes ligt tussen 0.5% en 1.5% voor de meeste scheepstypen terwijl de gemiddelde kans op een ongeval, bij elkaar voor alle scheepstypen, 0.06% is voor “zeer ernstige”,1.6% voor “ernstige-” en 1% voor “minder ernstige-” ongevallen.

De waarschijnlijkheid van aanhoudingsmodellen wijst uit dat het grootste aandeel aan gebreken die tot aanhoudingen leiden ligt op het gebied van certificaten, scheeps- en ladingsoperaties, de ISM[122]-code en veiligheids- en blusapparatuur, terwijl het kleinste aandeel op het gebied van machines en apparatuur blijkt te liggen.

De kans op een ongeval ofwel op basis van “ernst van ongeval” danwel “eerste incident ongeval” heeft ook drie aandachtsgebieden blootgelegd – de ISM-code, scheeps- en ladingsoperaties en machines en apparatuur. Dit zijn de belangrijkste gebieden die onderkend zijn, waar ruimte voor verbetering van PSC-inspecties bestaat zodat de kans op een ongeval afneemt.

[122] International Safety Management Code

Summary in Spanish (Resumen en Español)

La presente tesis debe ser vista y comprendida como un primer intento por analizar el control por el Estado rector del puerto (ERP) a escala global, midiendo los efectos de las inspecciones sobre la probabilidad de siniestros e identificar áreas para su mejora. Lo novedoso de esta tesis es la combinación de datos sobre control por el Estado rector de varios regímenes por un lado y datos de siniestros tomados de tres fuentes diferentes dentro de un mismo marco cronológico por el otro. Los planteos de investigación correspondientes son: 1) ¿En qué estado se encuentra el actual régimen de seguridad?, 2) ¿Puede mejorarse el factor de prioridad para las inspecciones de los buques?, 3) ¿Cuál es la repercusión de las inspecciones en los siniestros? y 4) ¿Cómo pueden mejorarse las inspecciones? Para el análisis se han utilizado tres grupos de datos de aproximadamente 183.000 inspecciones de varios Memorandos de Entendimiento (MoU[123]) para el período comprendido entre enero de 1999 y diciembre de 2004 y de aproximadamente 11.000 registros para el período 1993 – 2004.

La industria marítima se caracteriza por tener un marco legal muy engorroso basado en el derecho internacional con limitadas posibilidades de aplicación de la ley en caso de incumplimientos. Esto crea vacíos legales y distorsión de la competencia debido a la existencia de un mercado de buques subestandar. Desde una perspectiva pública, la situación deseada es promover un transporte marítimo seguro, protegido y compatible con el medio ambiente y reducir la cantidad de buques subestandar. Los Estados de abanderamiento deben ser vistos como la primera línea de defensa en la eliminación de este tipo de buques, seguidos por la segunda línea de defensa, los Estados rectores del puerto. La falta de confianza en la industria ha creado un campo propicio para las inspecciones a ciertos tipos de buques incluyendo una considerable cantidad realizadas por la propia industria estimándose un total de 11 por año para los buques tanque, 6 para los graneleros y 5 para los restantes tipos de buques.

Se han identificado dos áreas de mejora potencial: 1) el factor de prioridad de los buques para inspección y 2) las inspecciones y el seguimiento de las deficiencias mismas. A primera vista, parece que se priorizan muchos buques con cero deficiencias pero al sumarlos por buque y cruzarlos con los regímenes, el porcentaje de buques con cero deficiencias se reduce significativamente a lo largo del período dado. Sin embargo, se ha detectado que cierto grupo de buques (alrededor del 7% de los buques elegibles por el ERP) está sobre inspeccionado y deberían dirigirse los esfuerzos hacia los grupos de buques que pueden resultar beneficiados de una inspección. Basado en el período usado para este análisis el grupo que puede resultar beneficiado se estima en 14% de todos los buques elegidos para control por el Estado rector. La repercusión de las inspecciones por el Estado rector en las probabilidades de siniestros puede ser medida para los casos de siniestros muy graves pero no para los graves o menos graves. Dependiendo del perfil de riesgo general de un buque, una inspección puede potencialmente reducir la probabilidad de tener un siniestro grave en un 5% aproximadamente, mientras que la repercusión puede alcanzar un 10% para buques de alto riesgo.

Si bien las principales cifras sobre deficiencias y detenciones varían según cada régimen, las diferencias respecto de la probabilidad de detención se ven condicionadas por diferencias entre los Estados rectores y el trato de las deficiencias y no necesariamente

[123] Un memorando de entendimiento (MOU) es un documento legal que describe un acuerdo entre partes pero es menos formal que un contrato.

por la edad, las dimensiones, la bandera, la clase o el propietario. El factor de prioridad puede verse mejorado al desarrollar un factor de prioridad sobre datos de inspección combinados tomando en cuenta el historial total de inspección del buque y considerando las diferencias regionales dado que se han identificado zonas de alto riesgo para el período 1999 – 2004, como África Occidental, la región del Océano Índico, la del este del Océano Atlántico Norte, y el Mar del Sur de China. La diferencia en la repercusión de las inspecciones sobre la probabilidad de siniestros por casos graves de siniestros confirma un cambio en el rumbo de los buques subestandar de zonas como las del MOU de París y la Guardia Costera de los EE.UU. a otras zonas del globo, como las regiones de Sudamérica, el Océano Índico o Australia. Las inspecciones de estos regímenes han mostrado reducir la probabilidad de sufrir un siniestro en un nivel de importancia del 1%.

Las variables clásicas como tipo de buque, edad, dimensiones, bandera, sociedad de clasificación, deficiencias encontradas en inspecciones previas y detenciones son todas válidas para priorizar buques subestandar. El abanderamiento es solo una variable de las tantas que pueden ser usadas para priorizar buques subestandar. La edad solo sigue siendo relevante para los siniestros muy serios y a medida que la edad sube, la probabilidad de sufrir siniestros muy serios se incrementa en un 12% en un período de 35 años, el cual se traduce en un 0,35% por año. La probabilidad de siniestros también confirma que los buques de carga general son los que muestran la mayor probabilidad de siniestro, lo cual es confirmado por la probabilidad de detención. Los buques no inspeccionados o cuyas banderas figuran en listas negras muestran una mayor probabilidad de sufrir un siniestro muy grave comparados con los buques de banderas que aparecen en listas grises o blancas, aunque no se aplica lo mismo para siniestros graves o menos graves.

Otras mejoras en la priorización de buques subestandar pueden conseguirse al agregar la variable que indica el propietario o la Compañía que figura en el DoC[124] del buque y ciertos datos sobre el historial del buque, como cambios de clase, retiro de clase y cambio de propiedad en el tiempo o el lugar donde el buque fue mayormente construido, todo lo cual ha demostrado tener un efecto positivo o negativo sobre la probabilidad de siniestros. Otra posibilidad sería incluir si un buque ha sido inspeccionado por uno de los regímenes de exámenes previos (para cargas secas a granel) o certificado por la Greenaward Foundation.

Una visión más detallada sobre la efectividad de las inspecciones revela que la detención no parece ser importante para la probabilidad de sufrir un siniestro, lo cual es un resultado sorprendente. Ello no significa necesariamente que la detención no sea relevante sino que el efecto quizá pueda ser percibido por la inspección. Asimismo, el lapso entre inspecciones no resulta de importancia para siniestros muy graves, pero sí lo es para los graves o menos graves. En promedio y sin tomar en cuenta la gravedad del siniestro, la probabilidad se incrementa en 2,3% en el plazo de un año. El perfil de riesgo básico de los buques en todos los regímenes se halla entre 0,5% y 1,5% para la mayoría de los tipos de buques y regímenes, mientras que la probabilidad promedio de siniestros sumada para todos los tipos de buques se encontró en 0,06% para los siniestros muy graves, 1,6% para los graves y 1% para los menos graves.

Los modelos de probabilidad de detención develaron la más alta contribución de deficiencias en las detenciones en las áreas de certificados, operaciones de buque y de

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[124] Compañía que figura en el Documento de Cumplimiento, la compañía designada responsable de la gestión de la seguridad a bordo del buque de acuerdo con el Código Internacional de Gestión de la Seguridad (IGS)

carga, el código IGS[125] y seguridad y lucha contra incendios, mientras que la menor contribución se encuentra en máquinas y equipos. La probabilidad de siniestros por gravedad del mismo o por ocurrir por vez primera, también ha mostrado tres áreas de interés – el código IGS, las operaciones de buques y de carga y maquinas y equipo. Esas son las principales áreas identificadas donde existe lugar para una mejora a fin que las inspecciones por el Estado rector disminuyan la probabilidad de siniestros.

[125] Código Internacional de Gestión de la Seguridad

References

Most of the information which has contributed to this thesis derived from interviews, observations during ships inspections and attendance at sub-committee and committee meetings at IMO (International Maritime Organization) where some papers used are not accessible to the public or only at a later stage in the legislative process. In order to bring some structure to the different types of information sources used in this thesis, the list of references is split into different sections. The order of appearance in the list is given based on public accessibility of the resources.

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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.

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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 Superintendent: Mr. Cees-Willem Koorneef, Rotterdam, August 2004

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

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

Biography

Despite the author's origin from a non maritime nation, her life has been highly influenced by the seven seas. She received her first Master of Science degree from Maine Maritime Academy (USA) and served at sea for approximately 10 years of her life on cruise ships as hotel officer including onboard S.Y. Sea Cloud, one of the last historic tall ships still afloat and still in service. Sailing areas during her seagoing career on various other ships included most countries with access to the sea except parts of Africa, the North China Sea, the Bering Sea and Antarctica. Land based working experience includes primarily countries in North, Central and South America as well as the Caribbean where she worked in Tortola (British Virgin Islands) as port agent.

Her last land-based position was the establishment of the fleet auditor position for Carlson Companies, USA where she was responsible for six vessels. Carlson Companies is one of the largest privately owned companies in the USA and owns Regency Cruises (former Radisson Seven Seas Cruises). The fleet auditor position entailed constant travel across the globe but also permitted to be part of the management team of two new buildings and experiencing the maiden voyage of one of the vessels, the Seven Seas Mariner. Working in the cruise industry has trained her to function in a five star operation including working in a multicultural and multi-corporate environment where many nationalities have to cooperate to make the complex operation of a cruise vessel possible. Besides German and English, she is fluent in French and Spanish.

In autumn 2002, she recalled her European roots and returned back to the European Union and to university. She first studied Advanced European Studies with an emphasis on European Union law at Danube University, Austria and then moved to Rotterdam. She has been working on her PhD as a guest at the Econometric Institute of Erasmus University in the area of maritime safety from November 2004 onwards. She will continue her career in the shipping industry where her particular interest lies within the regulatory perspective of shipping including further applications of Econometrics to other segments of this industry and the increase of transparency and improvement of working and living conditions of seafarers.

Appendices

Note from the author:

Please note, that the full appendix is not included in the printed version of this thesis due to the large volume of pages. The appendix for further reference can be found under the following location: http://hdl.handle.net/1765/7913

Appendix 1: List of Member States of each MoU

Paris MoU	Caribbean MoU	Viña del Mar	Indian MoU	AMSA (Tokyo MoU)
Belgium	Anguilla	Argentina	Australia	Australia
Canada (1994)	Antigua & Barbuda	Bolivia (1999)	Bangladesh	Canada
Croatia (1997)	Aruba	Brazil	Djibouti	Chile (2002)
Denmark	Bahamas	Chile	Eritrea	China
Estonia (2005)	Barbados	Colombia	Ethiopia (Obs.)	Fiji (1996)
Finland	Bermuda	Cuba (1995)	India	Hong Kong
France	British Virgin Islands	Ecuador	Iran	Indonesia (1996)
Germany	Cayman Islands	Honduras (2001)	Kenya	Japan
Greece	Dominica	Mexico	Maldives	Republic of Korea
Iceland (2000)	Grenada	Panama	Mauritius	Malaysia
Ireland	Guyana	Peru	Mozambique	New Zealand
Italy	Jamaica	Uruguay	Myanmar	Papua New Guinea
Latvia (2005)	Montserrat	Venezuela	Oman	Philippines (1997)
Netherlands	Netherlands Antilles		Seychelles	Russian Fed. (1995)
Norway	St. Kitts & Nevis		South Africa	Singapore
Poland (1992)	St. Lucia		Sri Lanka	Solomon Islands *)
Portugal	St. Vinc.& Grenadines		Sudan	Thailand (1996)
Russian Fed. (1996)	Suriname		Tanzania	Vanuatu
Slovenia (2003)	Trinidad & Tobago		Yemen	Viet Nam (1999)
Spain	Turks & Caicos Islands			
Sweden	Cuba			**) not yet accepted*
UK	Dominican Republic			

Appendix 2: List of Detainable Deficiencies[126]

The following is a list of detainable deficiencies as per the IMO PSC Guidelines and are split up into the relevant legal bases:

SOLAS (all ships)

1. improper operation of propulsion or essential machinery
2. insufficient cleanliness in engines room, excessive dirty bilges, insulation of piping and contamination of oil, improper operation of bilge pumping arrangements
3. failure of proper operation of emergency generator, lighting, batteries and switches
4. failure of proper operation of main and auxiliary steering gear
5. absence or insufficient life savings appliances, survival craft and launching arrangements or serious deterioration thereof
6. non-functional fire fighting detection or fighting system or equipment including fire dampers and ventilation valves
7. absence or serious deterioration of fire fighting equipment of the cargo deck area for tankers.
8. absence or serious deterioration of lights, shapes or sound signals
9. absence or serious deterioration of radio equipment for distress and safety communication
10. absence of serious deterioration of navigational equipment
11. absence of corrected navigational charts or publications
12. absence of non-sparking exhaust ventilation for cargo pump rooms
13. number of crew does not match the safe manning certificate
14. non-implementation of the enhanced survey program when applicable

IBC and IGC Code (ships carrying dangerous cargo and gas carriers)

1. ship is carrying cargo not mentioned in the certificate of fitness or missing cargo information
2. missing or damaged high pressure safety devices
3. electrical installation not in compliance with IBC Code
4. sources of ignition in hazardous locations
5. exceeding of maximum allowable cargo quantity per tank
6. insufficient heat protection for sensitive products
7. missing closing devices for accommodation or service spaces
8. bulkhead not gastight
9. defective air locks
10. missing of defective quick-closing valves or safety valves
11. ventilation in cargo area not operable
12. pressure alarms for cargo tanks not operable
13. gas detection plant and/or toxic gas detection plant defective

Load Line Convention

1. significant damage or corrosion effecting seaworthiness of vessel
2. insufficient stability
3. absence of sufficient and reliable information for loading and ballasting of the vessel to maintain stability
4. absence or substantial deterioration of closing devices, hatch covers and watertight and weather tight doors
5. overloading
6. absence or impossible to read draught marks or load line marks

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[126] as per IMO guidelines on PSC, Chapter 2.3 and Appendix I (detainable deficiencies)

MARPOL Annex I, Annex II

1. malfunction of oily water separator
2. remaining capacity of slop/sludge tanks insufficient for the intended voyage
3. Oil Record Book not available
4. unauthorized discharge bypass fitted
5. failure to meet requirements of 13G(4) or 13G(7) – Crude Oil Washing
6. Absence of P&A Manual
7. Cargo is not categorized
8. No Cargo Record Book
9. Transport of oil-like substances without satisfying the requirement

STCW Convention

1. invalid certificate of competence or no endorsement by the flag state
2. failure to comply to safe manning requirements by the flag state
3. failure of navigational or engineering watch arrangements to conform to flag state requirements
4. absences in a watch of a qualified person to operate equipment for safe navigation, safety radio communications or the prevention of marine pollution
5. non compliance to sufficient rest periods

Appendix 3: IMO Definitions of Selected Major Ship Types[127]

Passenger Ship: ship that carries more than twelve passengers.

Cargo Ship: any ship which is not a passenger ship.

Tanker: cargo ship constructed or adapted for the carriage in bulk of liquid cargoes of an inflammable nature.

Oil Tanker: a ship constructed or adapted primarily to carry oil in bulk in its cargo spaces and includes the combination carriers and any "chemical tanker" when it is carrying a cargo or part cargo of oil in bulk. For the purpose of the Condition Assessment Scheme, oil tankers are divided into three categories as follows:

> <u>Category 1:</u> oil tanker of 20,000 tons deadweight and above carrying crude oil, fuel oil, heavy diesel oil or lubricating oil as cargo, and of 30,000 tons deadweight and above carrying oil other than the above, which does not comply with the requirements for new oil tankers as defined in regulation 1(26) of MARPOL Annex I.[128]
>
> <u>Category 2:</u> oil tanker of 20,000 tons deadweight and above carrying crude oil, fuel oil, heavy diesel oil or lubricating oil as cargo, and of 30,000 tons deadweight and above carrying oil other than the above, which complies with the requirements for new oil tankers as defined in regulation 1(26) of MARPOL Annex I.
>
> <u>Category 3:</u> oil tanker of 5,000 tons deadweight and above but less than that specified for category 1 and 2.

Combination Carrier: a ship designed to carry either oil or solid cargoes in bulk.

Chemical Tanker: is a cargo ship constructed or adapted and used for the carriage in bulk of any liquid product listed in either:

- Chapter 17 of the International Code for the Construction and Equipment of Ships Carrying Dangerous Chemicals in Bulk (IBC Code)
- Chapter VI of the Code for the Construction and Equipment of Ships Carrying Dangerous Chemicals in Bulk adopted by resolution A.212(VII).

Gas Carrier: a cargo ship constructed or adapted and used for the carriage in bulk of any liquefied gas or other products listed in either:

- Chapter 19 of the International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk (IGC Code)
- Chapter XIX of the Code for Construction and Equipment of Ships Carrying Liquefied Gases in Bulk adopted by resolution A.328 (IX).

Bulk Carrier: a ship which is constructed generally with single deck, top-side tanks and hopper side tanks in cargo spaces, and is intended primarily to carry dry cargo in bulk, and includes such types as ore carriers and combination carriers

Fishing Vessel: a vessel used for catching fish, whales, seals, walrus or other living resources of the sea.

Ro-Ro Passenger: a passenger ship with ro-ro cargo spaces or special category spaces as defined in regulation II-2/3. (SOLAS).

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[127] All sources of definitions are taken from SOLAS and MARPOL

[128] Refers to the date the vessel was built

Appendix 4: Variable List and Respective Coding for Regressions

The following list of variables shows a list of variables which have been used either in the probability of detention or probability of casualty models. Some variables are the same in both models while some variables only appear in one model. Due to the large size of variables in the detention models, only one ship type is shown below as an example. The detention models also use the following coding:

**) Variable+ Ship Type (e.g. GC) + PSC Regime (1 for Paris MoU)*

Type of Models - Codes Used		
Detention*)	**Casualty**	**Explanation of Variable**
IMO	IMO	IMO number of vessel
n/a	Casualty	ship had casualty (split into seriousness)
n/a	VerySerious	very serious casualty
n/a	Serious	serious casualty
n/a	LessSerious	less serious casualty
detained	detained	ship was detained
AgebyGC1	lnAge	Age at time of inspection/casualty
SizeGC1	lnTon	Gross Tonnage
n/a	ST1_max	general cargo ship
n/a	ST2_max	dry bulk carrier
n/a	ST3_max	container
n/a	ST4_max	tanker
n/a	ST5_max	passenger
n/a	ST6_max	other ship type
n/a	ST7_max	fishing vessel
CG	n/a	general cargo ship (middle portion of code)
DB	n/a	dry bulk carrier (middle portion of code)
CO	n/a	container (middle portion of code)
TA	n/a	tanker (middle portion of code)
PA	n/a	passenger (middle portion of code)
OT	n/a	other ship type (middle portion of code)
n/a	RS_Ins	ship inspected by Rightship
n/a	RS_1S	Rightship 1 star vessel
n/a	RS_2S	Rightship 2 star vessel
n/a	RS_3S	Rightship 3 star vessel
n/a	RS_4S	Rightship 4 star vessel
n/a	RS_5S	Rightship 5 star vessel
n/a	Green	ship is Greenaward certified
n/a	DH	double hull
n/a	STChgd	ship type changed
n/a	FLChgd	flag changed
n/a	CLChgd	classification society changed
n/a	CLWd_d	classification society withdrawn
n/a	OWChgd	ownership changed
1	n/a	Paris MoU (end portion of code)
2	n/a	Caribbean MoU (end portion of code)
3	n/a	Viña del Mar (end portion of code)
4	n/a	Indian Ocean MoU (end portion of code)
5	n/a	USCG (end portion of code)
6	n/a	AMSA (end portion of code)
n/a	PMOU_av	average inspection fraction Paris MoU

Type of Models - Codes Used		
Detention*)	**Casualty**	**Explanation of Variable**
n/a	CMOU_av	average inspection fraction Caribbean MoU
n/a	VMOU_av	average inspection fraction Viña del Mar MoU
n/a	IMOU_av	average inspection fraction Indian Ocean MoU
n/a	USCG_av	average inspection fraction USCG
n/a	AMSA_av	average inspection fraction AMSA
n/a	PMOU_s	number inspection fraction Paris MoU
n/a	CMOU_s	number inspection fraction Caribbean MoU
n/a	IMOU_s	number inspection fraction Indian Ocean MoU
n/a	VMOU_s	number inspection fraction Viña del Mar MoU
n/a	USCG_s	number inspection fraction USCG
n/a	AMSA_s	number inspection fraction AMSA
n/a	det_PMOU	detained by Paris MoU
n/a	det_CMOU	detained by Caribbean MoU
n/a	det_VMOU	detained by Viña del Mar MoU
n/a	det_IMOU	detained by Indian Ocean MoU
n/a	det_USCG	detained by USCG
n/a	det_AMSA	detained by AMSA
n/a	lnTimebw	time inbetween inspections
OWEMNGC1	OW_EMN	Owner from Emerging Maritime Nation
OWTMNGC1	OW_TMN	Owner from Traditional Maritime Nation
OWOORGC1	OW_OOR	Owner from Old Open Registry
OWNORGC1	OW_NOR	Owner from New Open Registry
OWIORGC1	OW_IOR	Owner from Intern. Open Registry
OWUNKGC1	OW_UNKn	Owner Unknown
n/a	LI_FLRet	Number of Legal Instruments Ratified by Flag
n/a	LI_OWRet	Number of Legal Instr. Ratified by Owner Country
FL_AFGC1	FL_AF	FL_Afghanistan
FL_ALGC1	FL_AL	FL_Albania
FL_DZGC1	FL_DZ	FL_Algeria
FL_AGGC1	FL_AG	FL_Antigua
FL_ANGC1	FL_AN	FL_AntillesNetherland
FL_ARGC1	FL_AR	FL_Argentina
FL_AUGC1	FL_AU	FL_Australia
FL_ATGC1	FL_AT	FL_Austria
FL_AZGC1	FL_AZ	FL_Azerbaijan
FL_BSGC1	FL_BS	FL_Bahamas
FL_DHGC1	FL_DH	FL_Bahrain
FL_BDGC1	FL_BD	FL_Bangladesh
FL_BBGC1	FL_BB	FL_Barbados
FL_BEGC1	FL_BE	FL_Belgium
FL_BZGC1	FL_BZ	FL_Belize
FL_BMGC1	FL_BM	FL_Bermuda
FL_BOGC1	FL_BO	FL_Bolivia
FL_BRGC1	FL_BR	FL_Brazil
FL_BGGC1	FL_BG	FL_Bulgaria
FL_BVIGC1	FL_BVI	FL_BVI
FL_KHGC1	FL_KH	FL_Cambodia
FL_CAGC1	FL_CA	FL_Canada
FL_KYGC1	FL_KY	FL_CaymanIslands
FL_CLGC1	FL_CL	FL_Chile
FL_CNGC1	FL_CN	FL_China
FL_COGC1	FL_CO	FL_Colombia

Type of Models - Codes Used		
Detention*)	**Casualty**	**Explanation of Variable**
FL_KMGC1	FL_KM	FL_Comoros
FL_HRGC1	FL_HR	FL_Croatia
FL_CUGC1	FL_CU	FL_Cuba
FL_CYGC1	FL_CY	FL_Cyprus
FL_DKGC1	FL_DK	FL_Denmark
FL_DMGC1	FL_DM	FL_Dominica
FL_DOGC1	FL_DO	FL_DominicanRepublic
FL_ECGC1	FL_EC	FL_Ecuador
FL_EGGC1	FL_EG	FL_Egypt
FL_ERGC1	FL_ER	FL_Eritrea
FL_EEGC1	FL_EE	FL_Estonia
FL_ETGC1	FL_ET	FL_Ethiopia
FL_FOGC1	FL_FO	FL_FaroeIslands
FL_FJGC1	FL_FJ	FL_Fiji
FL_FIGC1	FL_FI	FL_Finland
FL_FRGC1	FL_FR	FL_France
FL_GEGC1	FL_GE	FL_Georgia
FL_DEGC1	FL_DE	FL_Germany
FL_GIGC1	FL_GI	FL_Gibraltar
FL_GRGC1	FL_GR	FL_Greece
FL_GYGC1	FL_GY	FL_Guyana
FL_HTGC1	FL_HT	FL_Haiti
FL_HNGC1	FL_HN	FL_Honduras
FL_HKGC1	FL_HK	FL_HongKong
FL_ISGC1	FL_IS	FL_Iceland
FL_INGC1	FL_IN	FL_India
FL_IDGC1	FL_ID	FL_Indonesia
FL_IRGC1	FL_IR	FL_Iran
FL_IQGC1	FL_IQ	FL_Iraq
FL_IEGC1	FL_IE	FL_Ireland
FL_IMGC1	FL_IM	FL_IselofMan
FL_ILGC1	FL_IL	FL_Israel
FL_ITGC1	FL_IT	FL_Italy
FL_JMGC1	FL_JM	FL_Jamaica
FL_JPGC1	FL_JP	FL_Japan
FL_JOGC1	FL_JO	FL_Jordan
FL_KIGC1	FL_KI	FL_Kiribati
FL_KWGC1	FL_KW	FL_Kuwait
FL_LVGC1	FL_LV	FL_Latvia
FL_LBGC1	FL_LB	FL_Lebanon
FL_LRGC1	FL_LR	FL_Liberia
FL_LYGC1	FL_LY	FL_Libya
FL_LTGC1	FL_LT	FL_Lithuania
FL_LUGC1	FL_LU	FL_Luxembourg
FL_MYGC1	FL_MY	FL_Malaysia
FL_MVGC1	FL_MV	FL_Maldives
FL_MTGC1	FL_MT	FL_Malta
FL_MHGC1	FL_MH	FL_MarshallIslands
FL_MUGC1	FL_MU	FL_Mauritius
FL_MXGC1	FL_MX	FL_Mexico
FL_MDGC1	FL_MD	FL_Moldovia
FL_MNGC1	FL_MN	FL_Mongolia

Type of Models - Codes Used		
Detention*)	Casualty	Explanation of Variable
FL_MAGC1	FL_MA	FL_Morocco
FL_MMGC1	FL_MM	FL_Myanmar
FL_NAGC1	FL_NA	FL_Namibia
FL_NLGC1	FL_NL	FL_Netherlands
FL_NZGC1	FL_NZ	FL_NewZealand
FL_NIGC1	FL_NI	FL_Nicaragua
FL_NGGC1	FL_NG	FL_Nigeria
FL_NISGC1	FL_NIS	FL_NIS
FL_KPGC1	FL_KP	FL_NorthKorea
FL_NOGC1	FL_NO	FL_Norway
FL_OTGC1	FL_OT	FL_Other
FL_PKGC1	FL_PK	FL_Pakistan
FL_PAGC1	FL_PA	FL_Panama
FL_PYGC1	FL_PY	FL_Paraguay
FL_PEGC1	FL_PE	FL_Peru
FL_PHGC1	FL_PH	FL_Philippines
FL_PLGC1	FL_PL	FL_Poland
FL_PTGC1	FL_PT	FL_Portugal
FL_QAGC1	FL_QA	FL_Quatar
FL_ROGC1	FL_RO	FL_Romania
FL_RUGC1	FL_RU	FL_RussianFed
FL_ASGC1	FL_AS	FL_Samoa
FL_STGC1	FL_ST	FL_SaoTomePrin
FL_SAGC1	FL_SA	FL_SaudiaArabia
FL_SCGC1	FL_SC	FL_Seychelles
FL_SGGC1	FL_SG	FL_Singapore
FL_SKGC1	FL_SK	FL_Slovakia
FL_ZAGC1	FL_ZA	FL_SouthAfrica
FL_KRGC1	FL_KR	FL_SouthKorea
FL_ESGC1	FL_ES	FL_Spain
FL_LKGC1	FL_LK	FL_SriLanka
FL_VCGC1	FL_VC	FL_StVincentGrenad
FL_SDGC1	FL_SD	FL_Sudan
FL_SEGC1	FL_SE	FL_Sweden
FL_CHGC1	FL_CH	FL_Switzerland
FL_SYGC1	FL_SY	FL_Syria
FL_TWGC1	FL_TW	FL_Taiwan
FL_THGC1	FL_TH	FL_Thailand
FL_TOGC1	FL_TO	FL_Tonga
FL_TTGC1	FL_TT	FL_TrinidadTobago
FL_TNGC1	FL_TN	FL_Tunisia
FL_TRGC1	FL_TR	FL_Turkey
FL_TMGC1	FL_TM	FL_Turkmenistan
FL_TVGC1	FL_TV	FL_Tuvalu
FL_AEGC1	FL_AE	FL_UAE
FL_UKGC1	FL_UK	FL_UK
FL_UAGC1	FL_UA	FL_Ukraine
FL_UNGC1	FL_UN	FL_Unknown
FL_USGC1	FL_US	FL_USA
FL_VUGC1	FL_VU	FL_Vanuatu
FL_VEGC1	FL_VE	FL_Venezuela
FL_VNGC1	FL_VN	FL_VietNam

Type of Models - Codes Used		
Detention*)	**Casualty**	**Explanation of Variable**
CLABSGC1	CL_ABS	CL_ABS
CLBKGC1	CL_BKI	CL_BiroKlasIndo
CLBUKGC1	CL_BUK	CL_BulgarskiKoraben
CLBVGC1	CL_BV	CL_BureauVeritas
CLCCGC1	CL_CCS	CL_ChinaClass
CLCOOGC1	CL_CCO	CL_ChinaCorp
CLCRRGC1	CL_CRR	CL_CroatianRS
CLDNVGC1	CL_DNV	CL_DNV
CLGLGC1	CL_GL	CL_GermanischerLloyd
CLGBKGC1	CL_GBS	CL_GuardianBS
CLHELGC1	CL_HEL	CL_Hellenic
CLHINGC1	CL_HIN	CL_HondurasInterNav
CLINCGC1	CL_INC	CL_Inclamar
CLINRGC1	CL_INR	CL_IndianRegister
CLINSGC1	CL_INS	CL_InterNavSurB
CLIRSGC1	CL_IRS	CL_InterRegShipping
CLIBSGC1	CL_IBS	CL_IsthmusBS
CLJRSGC1	CL_JRS	CL_JosonRS
CLKRSGC1	CL_KRS	CL_KoreanSouth
CLLRGC1	CL_LR	CL_LloydsUK
CLNKKGC1	CL_NKK	CL_NKKJapan
CLNCLGC1	CL_NCL	CL_NoClass
CLOCLGC1	CL_OCL	CL_OtherClass
CLPBSGC1	CL_PBS	CL_PanamaBureauS
CLPMDGC1	CL_PMD	CL_PanamaMDS
CLPMSCG1	CL_PMS	CL_PanamaMSurveyorB
CLPRCGC1	CL_PRC	CL_PanamaRegCorp
CLPSRCG1	CL_PSR	CL_PanamaShipReg
CLPRSGC1	CL_PRS	CL_PolskiReSt
CLRSAGC1	CL_RSA	CL_RegisterAlbania
CLRCCGC1	CL_RCC	CL_RegistroCubano
CLRSCGC1	CL_RSC	CL_RegShipChina
CLRSKGC4	CL_RSK	CL_RegShipDRKorea
CLRSGGC1	CL_RSG	CL_RegShipGhana
CLRINGC1	CL_RIN	CL_RINA
CLRIPGC1	CL_RIP	CL_RINAVE
CLRNRGC1	CL_RNR	CL_RomanianNaval
CLRMSGC1	CL_RMS	CL_RussianMS
CLRRRGC1	CL_RRR	CL_RussianRiver
CLSRUGC1	CL_SRU	CL_SRUkraine
CLTLLGC1	CL_TLL	CL_TurkishLloyd
CLVRSGC1	CL_VRS	CL_VietnamRS
C0100GC1	Code_0100	Ship's certificates and documents
C0200GC1	Code_0200	Crew certificates
C0300GC1	Code_0300	Accommodation
C0400GC1	Code_0400	Food and catering
C0500GC1	Code_0500	Working spaces and accident prev.
C0600GC1	Code_0600	Life saving appliances
C0700GC1	Code_0700	Fire Safety measures
C0800GC1	Code_0800	Accident prevention (ILO147)
C0900GC1	Code_0900	Structural Safety
C1000GC1	Code_1000	Alarm signals

Type of Models - Codes Used		
Detention*)	**Casualty**	**Explanation of Variable**
C1100GC1	Code_1100	Cargoes
C1200GC1	Code_1200	Load lines
C1300GC1	Code_1300	Mooring arrangements (ILO 147)
C1400GC1	Code_1400	Propulsion & auxiliary engine
C1500GC1	Code_1500	Safety of navigation
C1600GC1	Code_1600	Radio communications
C1700GC1	Code_1700	MARPOL Annex I
C1800GC1	Code_1800	Gas and chemical carriers
C1900GC1	Code_1900	MARPOL Annex II
C2000GC1	Code_2000	SOLAS Operational deficiencies
C2100GC1	Code_2100	MARPOL related oper. deficiencies
C2200GC1	Code_2200	MARPOL Annex III
C2300GC1	Code_2300	MARPOL Annex V
C2500GC1	Code_2500	ISM related deficiencies
C2600GC1	Code_2600	Bulk carriers
C2700GC1	Code_2700	Security
C2900GC1	Code_2900	MARPOL Annex IV
C9800GC1	Code_9800	Other def. clearly hazardous safety
C9900GC1	Code_9900	Other def. not clearly hazardous
PS1_BE	PS1_BE	PS1_Belgium
PS1_CA	PS1_CA	PS1_Canada
PS1_HR	PS1_HR	PS1_Croatia
PS1_DK	PS1_DK	PS1_Denmark
PS1_FI	PS1_FI	PS1_Finland
PS1_FR	PS1_FR	PS1_France
PS1_DE	PS1_DE	PS1_Germany
PS1_GR	PS1_GR	PS1_Greece
PS1_IS	PS1_IS	PS1_Iceland
PS1_IE	PS1_IE	PS1_Ireland
PS1_IT	PS1_IT	PS1_Italy
PS1_NL	PS1_NL	PS1_Netherlands
PS1_NO	PS1_NO	PS1_Norway
PS1_PL	PS1_PL	PS1_Poland
PS1_PT	PS1_PT	PS1_Portugal
PS1_RU	PS1_RU	PS1_Russia
PS1_SI	PS1_SI	PS1_Slovenia
PS1_ES	PS1_ES	PS1_Spain
PS1_SE	PS1_SE	PS1_Sweden
PS1_UK	PS1_UK	PS1_UK
PS2_AG	PS2_AG	PS2_Antigua
PS2_AN	PS2_AN	PS2_AntillesNetherlands
PS2_BS	PS2_BS	PS2_Bahamas
PS2_BB	PS2_BB	PS2_Barbados
PS2_BVI	PS2_BVI	PS2_BVI
PS2_KY	PS2_KY	PS2_Cayman
PS2_CU	PS2_CU	PS2_Cuba
PS2_JM	PS2_JM	PS2_Jamaica
PS2_VC	PS2_VC	PS2_StVincentGren
PS2_SR	PS2_SR	PS2_Suriname
PS2_TT	PS2_TT	PS2_Trinidad
PS3_AR	PS3_AR	PS3_Argentina
PS3_BR	PS3_BR	PS3_Brasil

Type of Models - Codes Used		
Detention*)	Casualty	Explanation of Variable
PS3_CHI	PS3_CHI	PS3_Chile
PS3_COL	PS3_COL	PS3_Colombia
PS3_CUB	PS3_CUB	PS3_Cuba
PS3_ECU	PS3_ECU	PS3_Ecuador
PS3_HN	PS3_HN	PS3_Honduras
PS3_MX	PS3_MX	PS3_Mexico
PS3_PA	PS3_PA	PS3_Panama
PS3_PE	PS3_PE	PS3_Peru
PS3_UY	PS3_UY	PS3_Uruguay
PS3_VE	PS3_VE	PS3_Venezuela
PS4_ER	PS4_ER	PS4_Eritrea
PS4_IN	PS4_IN	PS4_India
PS4_IR	PS4_IR	PS4_Iran
PS4_MU	PS4_MU	PS4_Mauritius
PS4_ZA	PS4_ZA	PS4_SouthAfrica
PS4_LK	PS4_LK	PS4_SriLanka
PS4_SD	PS4_SD	PS4_Sudan
PS4_TZ	PS4_TZ	PS4_Tanzania
PS5_ANCO	PS5_ANCO	PS5_Anchorage_AK
PS5_BALTI	PS5_BALTI	PS5_Baltimore_MD
PS5_BATR	PS5_BATR	PS5_BatonRouge_LA
PS5_BOST	PS5_BOST	PS5_Boston_MA
PS5_BROW	PS5_BROW	PS5_Brownsville_TX
PS5_BUFF	PS5_BUFF	PS5_Buffalo_NY
PS5_CHAR	PS5_CHAR	PS5_Charleston_SC
PS5_CHIC	PS5_CHIC	PS5_Chicago_IL
PS5_CLEV	PS5_CLEV	PS5_Cleveland_OH
PS5_CORP	PS5_CORP	PS5_CorpusChristi_TX
PS5_DETR	PS5_DETR	PS5_Detroit_MI
PS5_DULU	PS5_DULU	PS5_Duluth_MN
PS5_GUAM	PS5_GUAM	PS5_Guam
PS5_HAMP	PS5_HAMP	PS5_HamptonRoads_VA
PS5_HONO	PS5_HONO	PS5_Honolulu_HI
PS5_HOUS	PS5_HOUS	PS5_HoustonGalv_TX
PS5_JACK	PS5_JACK	PS5_Jacksonville_FL
PS5_JUNE	PS5_JUNE	PS5_Juneau_AK
PS5_LCHA	PS5_LCHA	PS5_LakeCharles_LA
PS5_LONG	PS5_LONG	PS5_LongIsland_NY
PS5_LANG	PS5_LANG	PS5_LosAngeles_CA
PS5_MASS	PS5_MASS	PS5_Massena_NY
PS5_MIAM	PS5_MIAM	PS5_Miami_FL
PS5_MOBI	PS5_MOBI	PS5_Mobile_AL
PS5_MORG	PS5_MORG	PS5_MorganCity_LA
PS5_NORL	PS5_NORL	PS5_NewOrleans_LA
PS5_NEWY	PS5_NEWY	PS5_NewYork_NY
PS5_PHIL	PS5_PHIL	PS5_Philadelphia_PA
PS5_POAR	PS5_POAR	PS5_PortArthur_TX
PS5_POCA	PS5_POCA	PS5_PortCarnaveral_FL
PS5_POLA	PS5_POLA	PS5_PortLavaca_TX
PS5_PORM	PS5_PORM	PS5_Portland_ME
PS5_PORO	PS5_PORO	PS5_Portland_OR
PS5_PORT	PS5_PORT	PS5_Portsmouth_NH

Type of Models - Codes Used		
Detention*)	**Casualty**	**Explanation of Variable**
PS5_PROV	PS5_PROV	PS5_Providence_RI
PS5_PUGE	PS5_PUGE	PS5_PugetSound_WA
PS5_SAMO	PS5_SAMO	PS5_AmericanSamoa
PS5_SAND	PS5_SAND	PS5_SanDiego_CL
PS5_SANF	PS5_SANF	PS5_SanFrancisco_CL
PS5_SANJ	PS5_SANJ	PS5_SanJuan_PR
PS5_SANB	PS5_SANB	PS5_SantaBarbara_CL
PS5_SAUL	PS5_SAUL	PS5_SaultMarie_MI
PS5_SAVA	PS5_SAVA	PS5_Savannah_GA
PS5_TAMP	PS5_TAMP	PS5_Tampa_FL
PS5_TOLE	PS5_TOLE	PS5_Toledo_OH
PS5_VALD	PS5_VALD	PS5_Valdez_AK
PS5_WILM	PS5_WILM	PS5_Wilmington_NC
PS5_USVI	PS5_USVI	PS5_USVirginIslands
PS5_OTH	PS5_OTH	PS5_Other
PS6_BELL	PS6_BELL	PS6_BellBay_TAS
PS6_BRIS	PS6_BRIS	PS6_Brisbane_QLD
PS6_BUNB	PS6_BUNB	PS6_Bunbury_WA
PS6_BURN	PS6_BURN	PS6_Burnie_TAS
PS6_CAIR	PS6_CAIR	PS6_Cairns_QLD
PS6_DAMP	PS6_DAMP	PS6_Dampier_WA
PS6_DARW	PS6_DARW	PS6_Darwin_NT
PS6_DEVO	PS6_DEVO	PS6_Devonport_TAS
PS6_ESPE	PS6_ESPE	PS6_Esperance_WA
PS6_FREM	PS6_FREM	PS6_Fremantle_WA
PS6_GEEL	PS6_GEEL	PS6_Geelong_VIC
PS6_GERA	PS6_GERA	PS6_Geraldton_WA
PS6_GLAD	PS6_GLAD	PS6_Gladstone_QLD
PS6_GOVE	PS6_GOVE	PS6_Gove_NT
PS6_HAYP	PS6_HAYP	PS6_HayPoint_QLD
PS6_KURN	PS6_KURN	PS6_Kurnell_NSW
PS6_KWIN	PS6_KWIN	PS6_Kwinana_WA
PS6_MACK	PS6_MACK	PS6_Mackay_QLD
PS6_MELB	PS6_MELB	PS6_Melborne_VIC
PS6_NEWC	PS6_NEWC	PS6_Newcastle_NSW
PS6_OTH	PS6_OTH	PS6_Other
PS6_POAD	PS6_POAD	PS6_PortAdelaide_SA
PS6_POBO	PS6_POBO	PS6_PortBotany_NSW
PS6_POHE	PS6_POHE	PS6_PortHedland_WA
PS6_POKE	PS6_POKE	PS6_PortKembla_NSW
PS6_POWA	PS6_POWA	PS6_PortWalcott_WA
PS6_PORT	PS6_PORT	PS6_Portland_VIC
PS6_SYDN	PS6_SYDN	PS6_Sydney_NSW
PS6_TOWN	PS6_TOWN	PS6_Townsville_QLD
PS6_WALL	PS6_WALL	PS6_Wallaroo_SA
n/a	SY_AU	Australia
n/a	SY_BE	Belgium
n/a	SY_BR	Brazil
n/a	SY_BG	Bulgaria
n/a	SY_CA	Canada
n/a	SY_CL	Chile
n/a	SY_CN	China

Type of Models - Codes Used		
Detention*)	Casualty	Explanation of Variable
n/a	SY_HR	Croatia
n/a	SY_DK	Denmark
n/a	SY_FI	Finland
n/a	SY_FR	France
n/a	SY_DE	Germany
n/a	SY_GR	Greece
n/a	SY_IN	India
n/a	SY_ID	Indonesia
n/a	SY_IT	Italy
n/a	SY_JP	Japan
n/a	SY_MY	Malaysia
n/a	SY_NL	Netherlands
n/a	SY_NO	Norway
n/a	SY_OT	Other
n/a	SY_PH	Philippines
n/a	SY_PL	Poland
n/a	SY_PT	Portugal
n/a	SY_RO	Romania
n/a	SY_RU	Russian Federation
n/a	SY_SG	Singapore
n/a	SY_KR	South Korea
n/a	SY_ES	Spain
n/a	SY_SE	Sweden
n/a	SY_TW	Taiwan
n/a	SY_TR	Turkey
n/a	SY_UA	Ukraine
n/a	SY_UK	United Kingdom
n/a	SY_US	United States of America
n/a	SY_UN	Unknown
n/a	SY_VN	Viet Nam

Appendix 5: 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

Appendix 6: Results of Correspondence Analysis for Ship Type Selection

please refer to http://hdl.handle.net/1765/7913

Appendix 7: Step 3: Final Models: General Cargo

please refer to http://hdl.handle.net/1765/7913

Appendix 8: Step 3: Final Models: Dry Bulk

please refer to http://hdl.handle.net/1765/7913

Appendix 9: Step 3: Final Models: Tanker

please refer to http://hdl.handle.net/1765/7913

Appendix 10: Step 3: Final Models: Container

please refer to http://hdl.handle.net/1765/7913

Appendix 11: Step 1: Results of Regressions: Passenger Vessels

please refer to http://hdl.handle.net/1765/7913

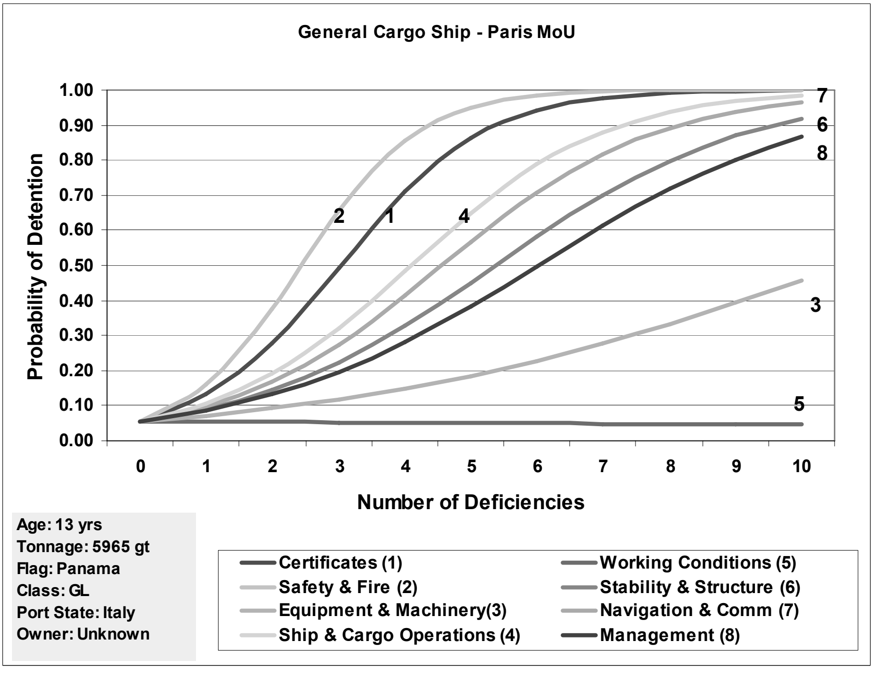
Appendix 12: Step 1: Results of Regressions: Other Ship Types

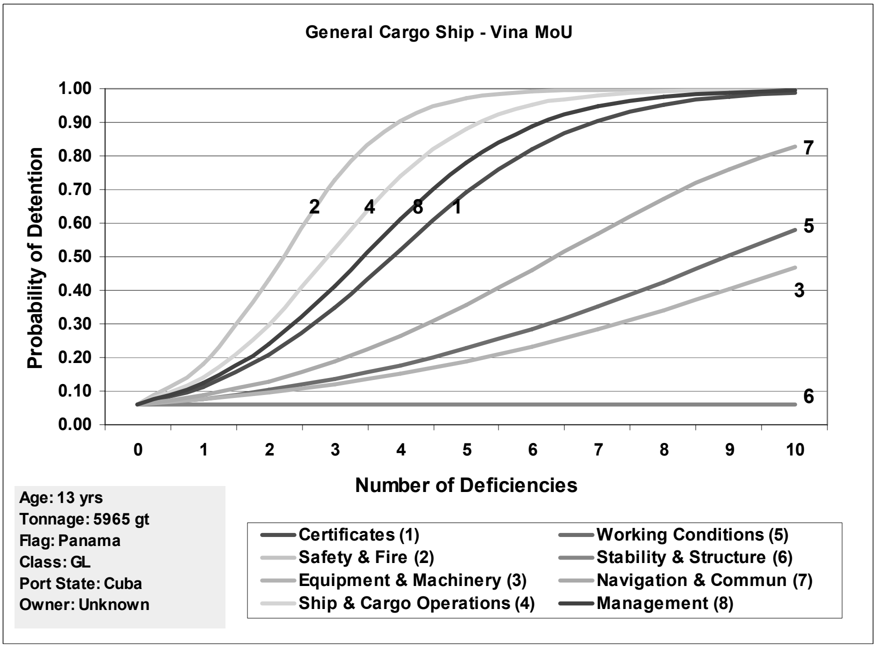
please refer to http://hdl.handle.net/1765/7913

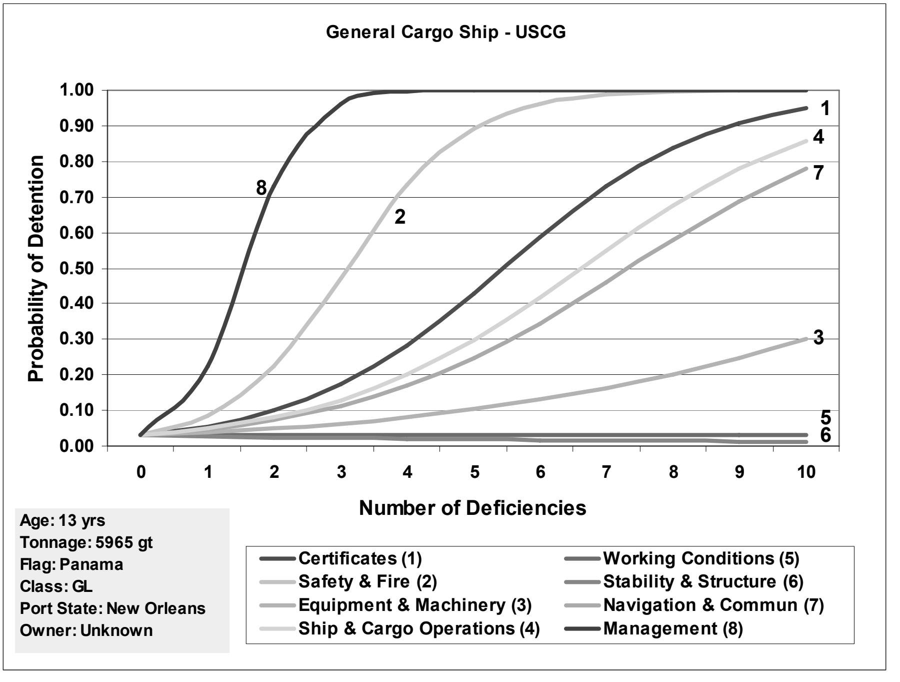
Appendix 13: Step 1: Results of Regressions: Caribbean MoU

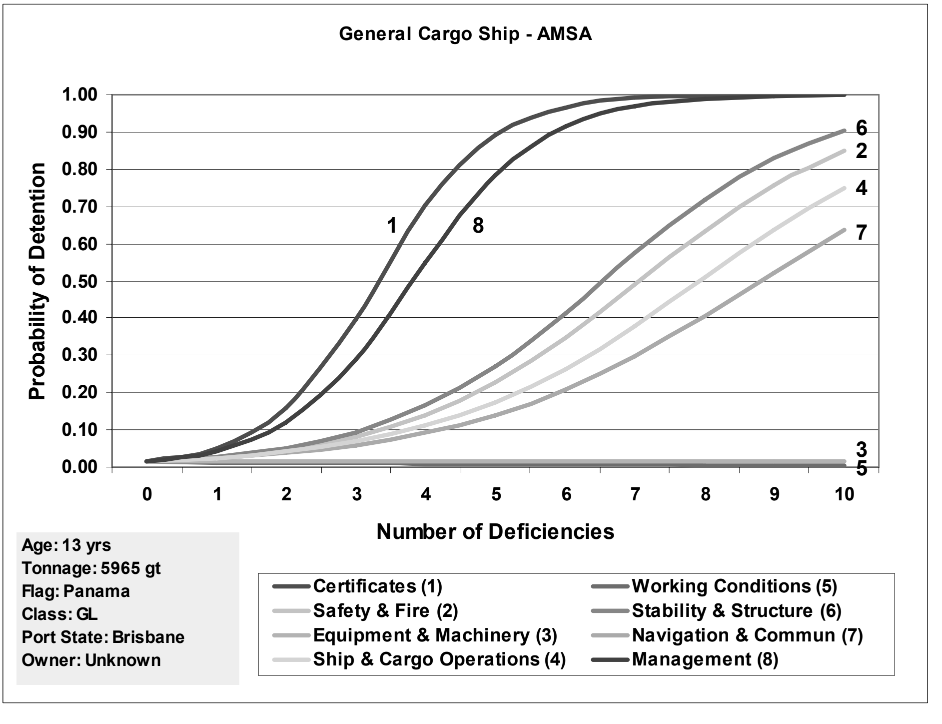
please refer to http://hdl.handle.net/1765/7913

Appendix 14: Step 3: Probability of Detention: General Cargo

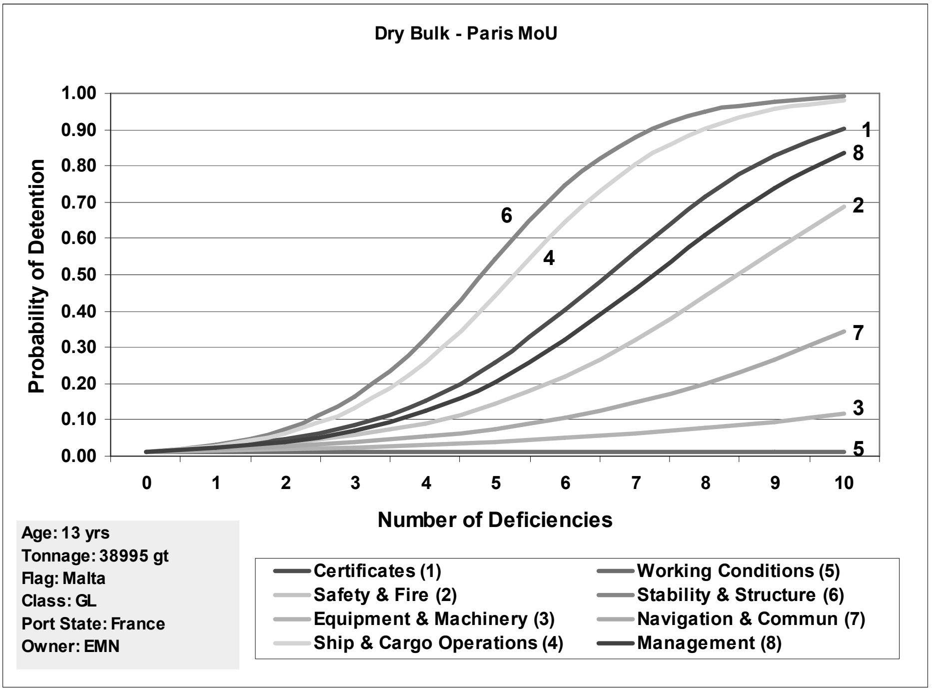


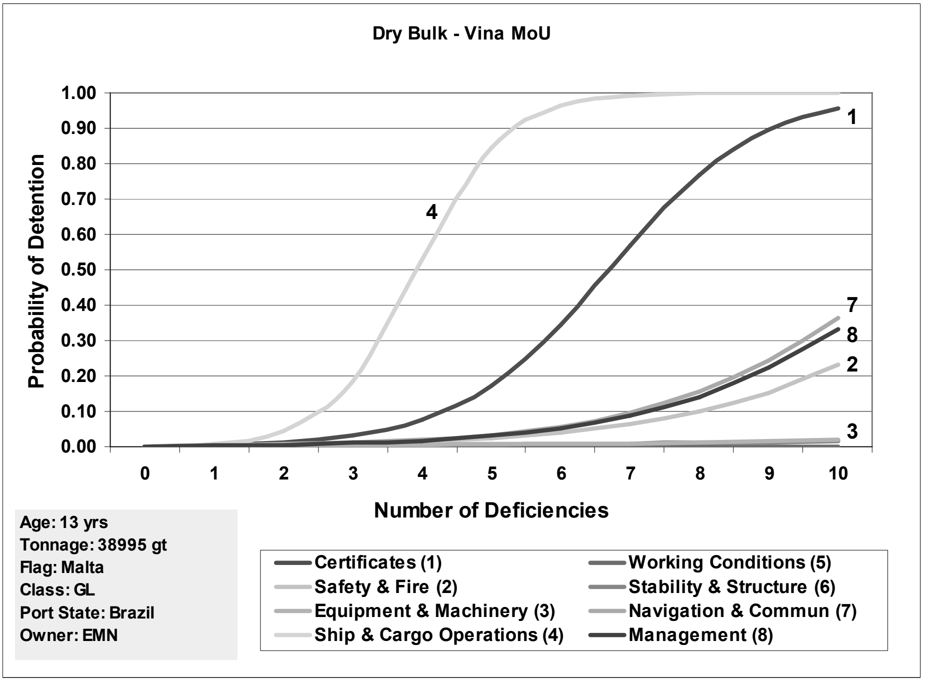


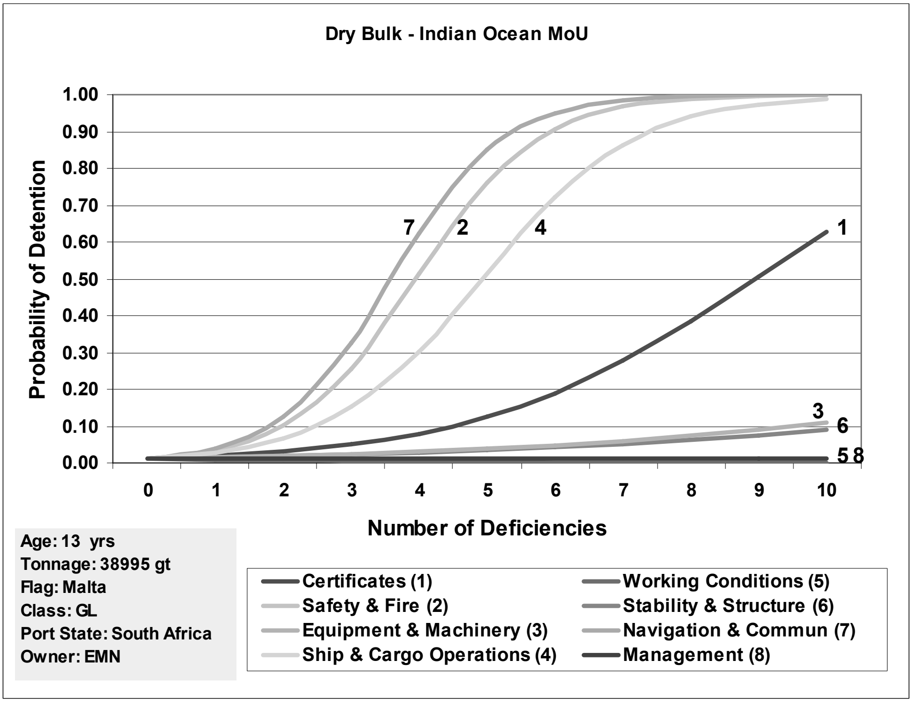

General Cargo Ship - USCG
Probability of Detention
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
0 1 2 3 4 5 6 7 8 9 10
Number of Deficiencies
8
2
1
4
7
3
5
6
Age: 13 yrs
Tonnage: 5965 gt
Flag: Panama
Class: GL
Port State: New Orleans
Owner: Unknown
Certificates (1)
Safety & Fire (2)
Equipment & Machinery (3)
Ship & Cargo Operations (4)
Working Conditions (5)
Stability & Structure (6)
Navigation & Commun (7)
Management (8)

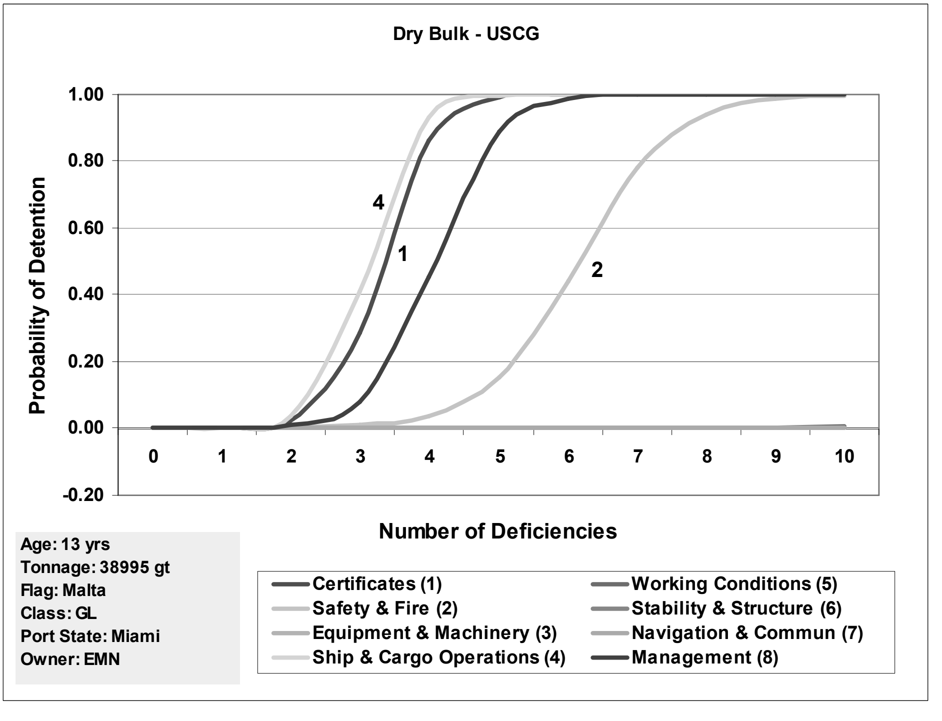

General Cargo Ship - AMSA
Probability of Detention
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
0 1 2 3 4 5 6 7 8 9 10
Number of Deficiencies
1
8
6
2
4
7
3
5
Age: 13 yrs
Tonnage: 5965 gt
Flag: Panama
Class: GL
Port State: Brisbane
Owner: Unknown
Certificates (1)
Safety & Fire (2)
Equipment & Machinery (3)
Ship & Cargo Operations (4)
Working Conditions (5)
Stability & Structure (6)
Navigation & Commun (7)
Management (8)

Appendix 15: Step 3: Probability of Detention: Dry Bulk

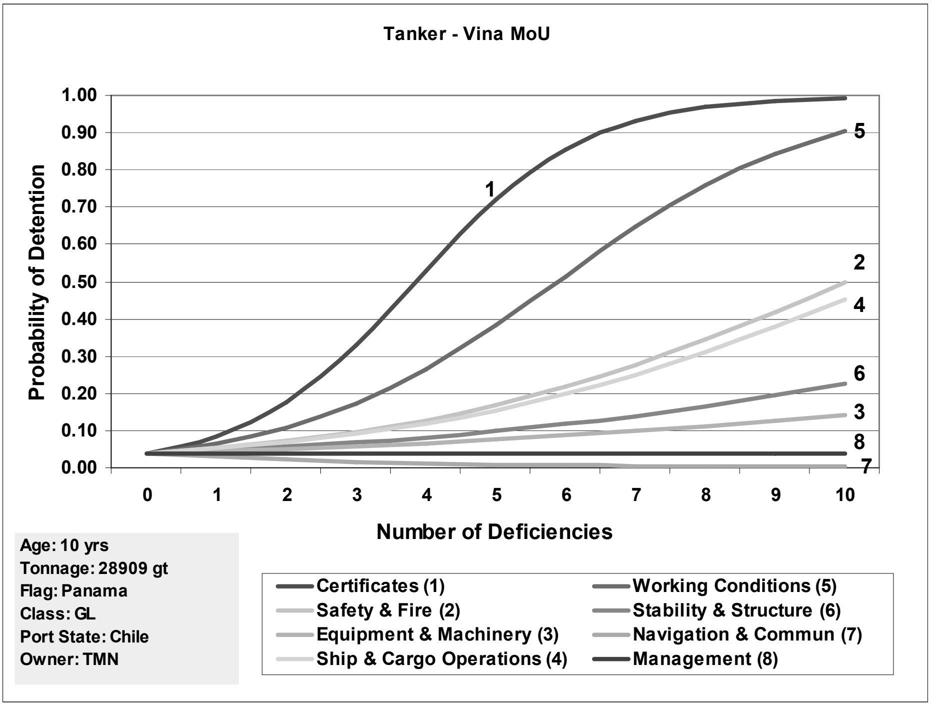


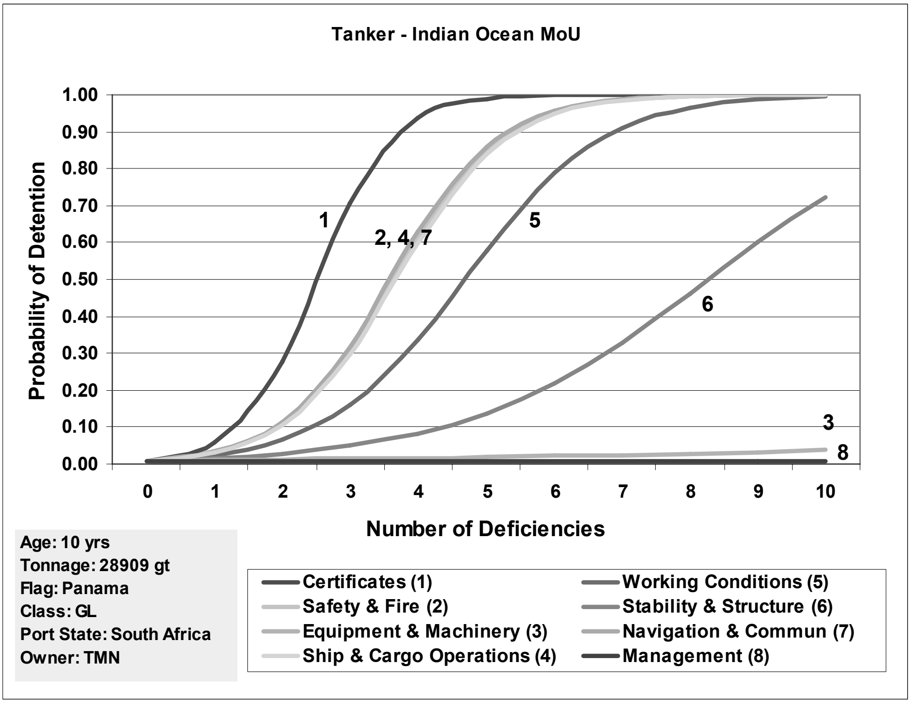


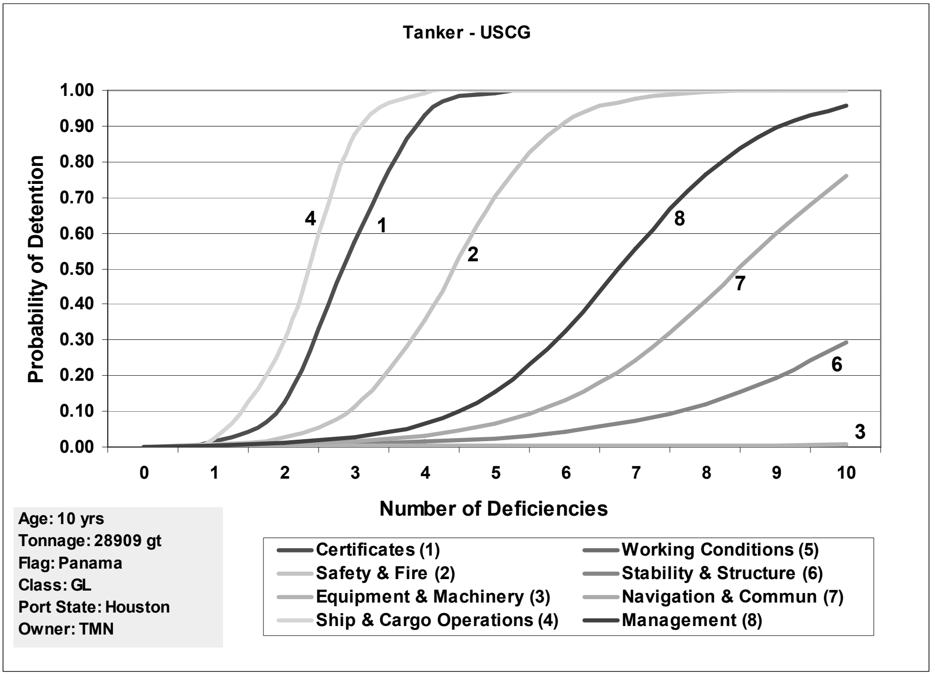

Dry Bulk - Indian Ocean MoU
Probability of Detention
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
0
1
2
3
4
5
6
7
8
9
10
7
2
4
1
3
6
5 8
Number of Deficiencies
Age: 13 yrs
Tonnage: 38995 gt
Flag: Malta
Class: GL
Port State: South Africa
Owner: EMN
Certificates (1)
Safety & Fire (2)
Equipment & Machinery (3)
Ship & Cargo Operations (4)
Working Conditions (5)
Stability & Structure (6)
Navigation & Commun (7)
Management (8)

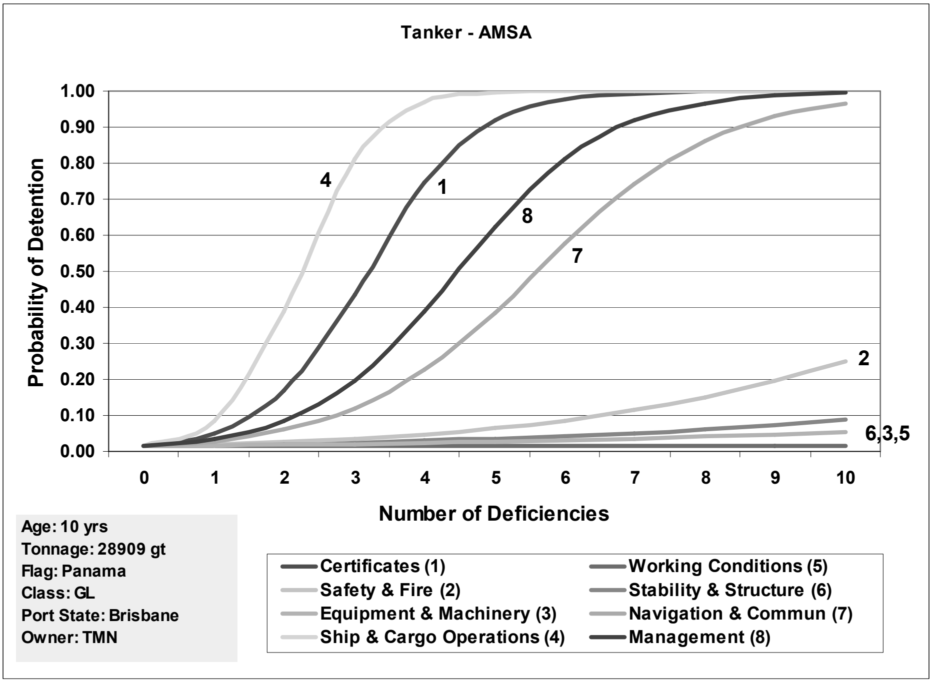

Dry Bulk - USCG
Probability of Detention
1.00
0.80
0.60
0.40
0.20
0.00
-0.20
0
1
2
3
4
5
6
7
8
9
10
4
1
2
Number of Deficiencies
Age: 13 yrs
Tonnage: 38995 gt
Flag: Malta
Class: GL
Port State: Miami
Owner: EMN
Certificates (1)
Safety & Fire (2)
Equipment & Machinery (3)
Ship & Cargo Operations (4)
Working Conditions (5)
Stability & Structure (6)
Navigation & Commun (7)
Management (8)

Appendix 16: Step 3: Probability of Detention: Tanker

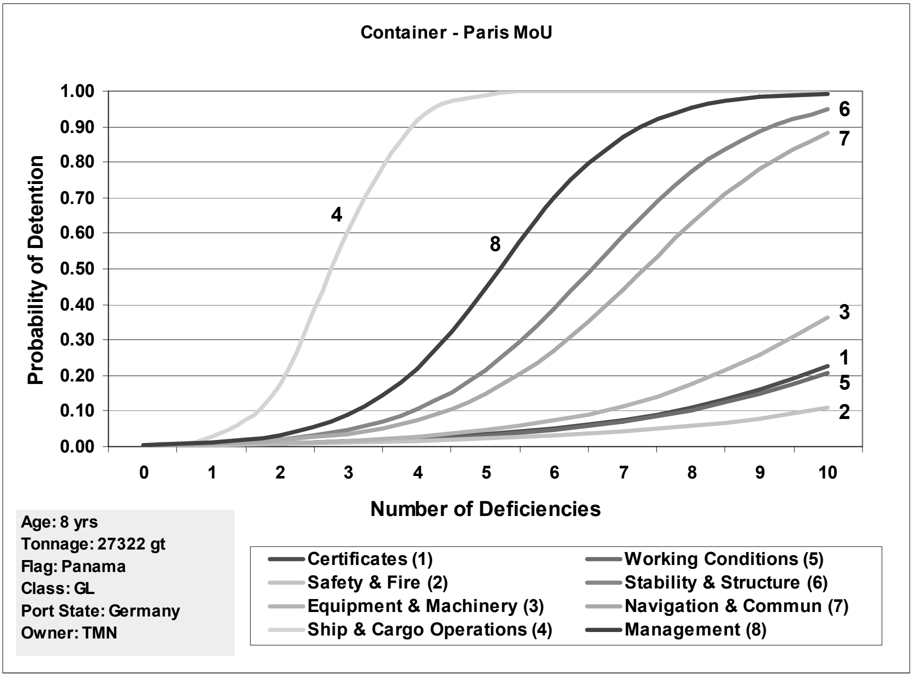


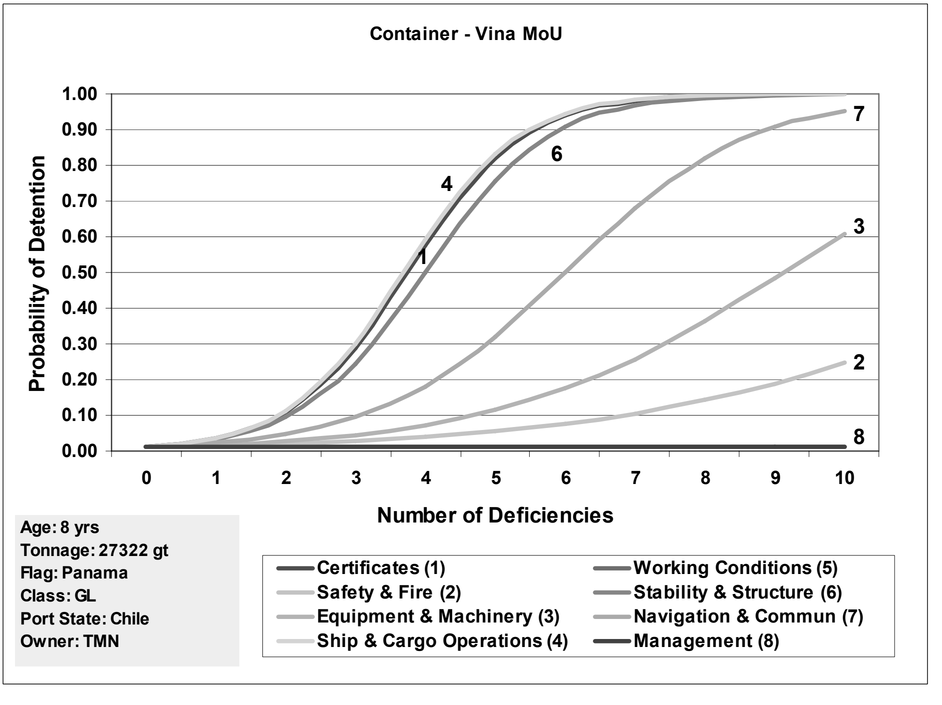


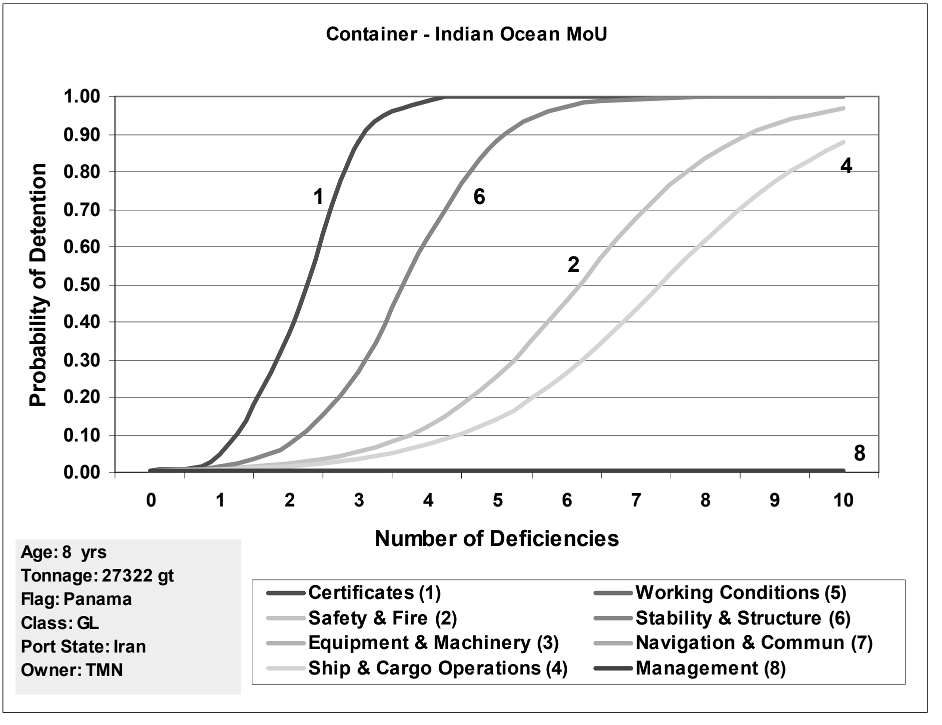

Tanker - USCG
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
Probability of Detention
4
1
2
8
7
6
3
0 1 2 3 4 5 6 7 8 9 10
Number of Deficiencies
Age: 10 yrs
Tonnage: 28909 gt
Flag: Panama
Class: GL
Port State: Houston
Owner: TMN
Certificates (1)
Safety & Fire (2)
Equipment & Machinery (3)
Ship & Cargo Operations (4)
Working Conditions (5)
Stability & Structure (6)
Navigation & Commun (7)
Management (8)

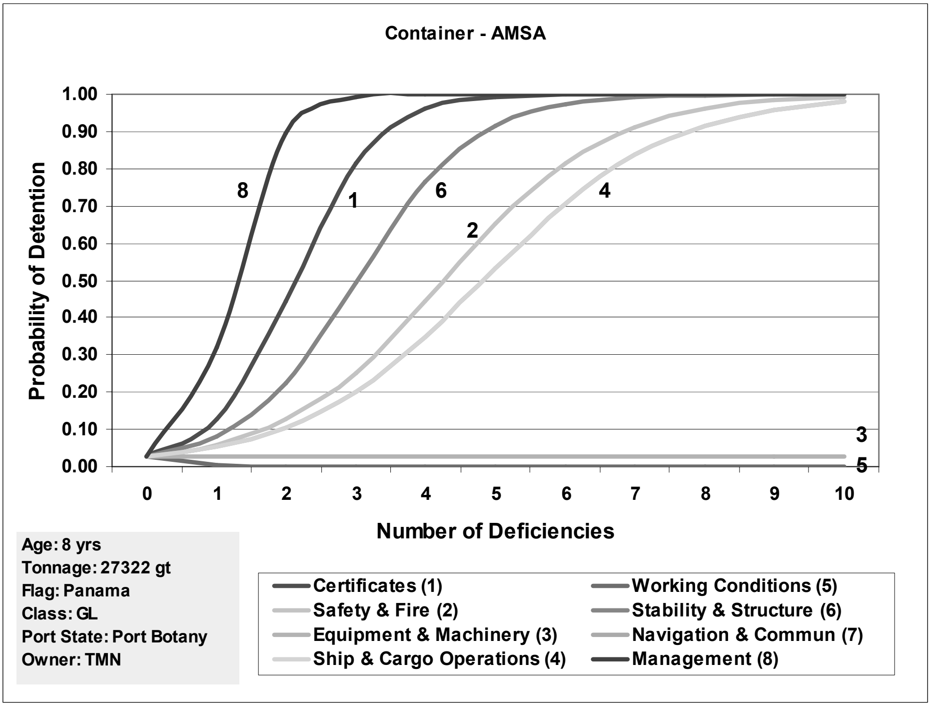

Tanker - AMSA
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
Probability of Detention
4
1
8
7
2
6,3,5
0 1 2 3 4 5 6 7 8 9 10
Number of Deficiencies
Age: 10 yrs
Tonnage: 28909 gt
Flag: Panama
Class: GL
Port State: Brisbane
Owner: TMN
Certificates (1)
Safety & Fire (2)
Equipment & Machinery (3)
Ship & Cargo Operations (4)
Working Conditions (5)
Stability & Structure (6)
Navigation & Commun (7)
Management (8)

Appendix 17: Step 3: Probability of Detention: Container






Container - Indian Ocean MoU
Probability of Detention
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
0 1 2 3 4 5 6 7 8 9 10
Number of Deficiencies
1
6
2
4
8
Age: 8 yrs
Tonnage: 27322 gt
Flag: Panama
Class: GL
Port State: Iran
Owner: TMN
Certificates (1)
Safety & Fire (2)
Equipment & Machinery (3)
Ship & Cargo Operations (4)
Working Conditions (5)
Stability & Structure (6)
Navigation & Commun (7)
Management (8)


Container - AMSA
Probability of Detention
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
0 1 2 3 4 5 6 7 8 9 10
Number of Deficiencies
8
1
6
2
4
3
5
Age: 8 yrs
Tonnage: 27322 gt
Flag: Panama
Class: GL
Port State: Port Botany
Owner: TMN
Certificates (1)
Safety & Fire (2)
Equipment & Machinery (3)
Ship & Cargo Operations (4)
Working Conditions (5)
Stability & Structure (6)
Navigation & Commun (7)
Management (8)

Appendix 18: LM Test for Very Serious Casualties

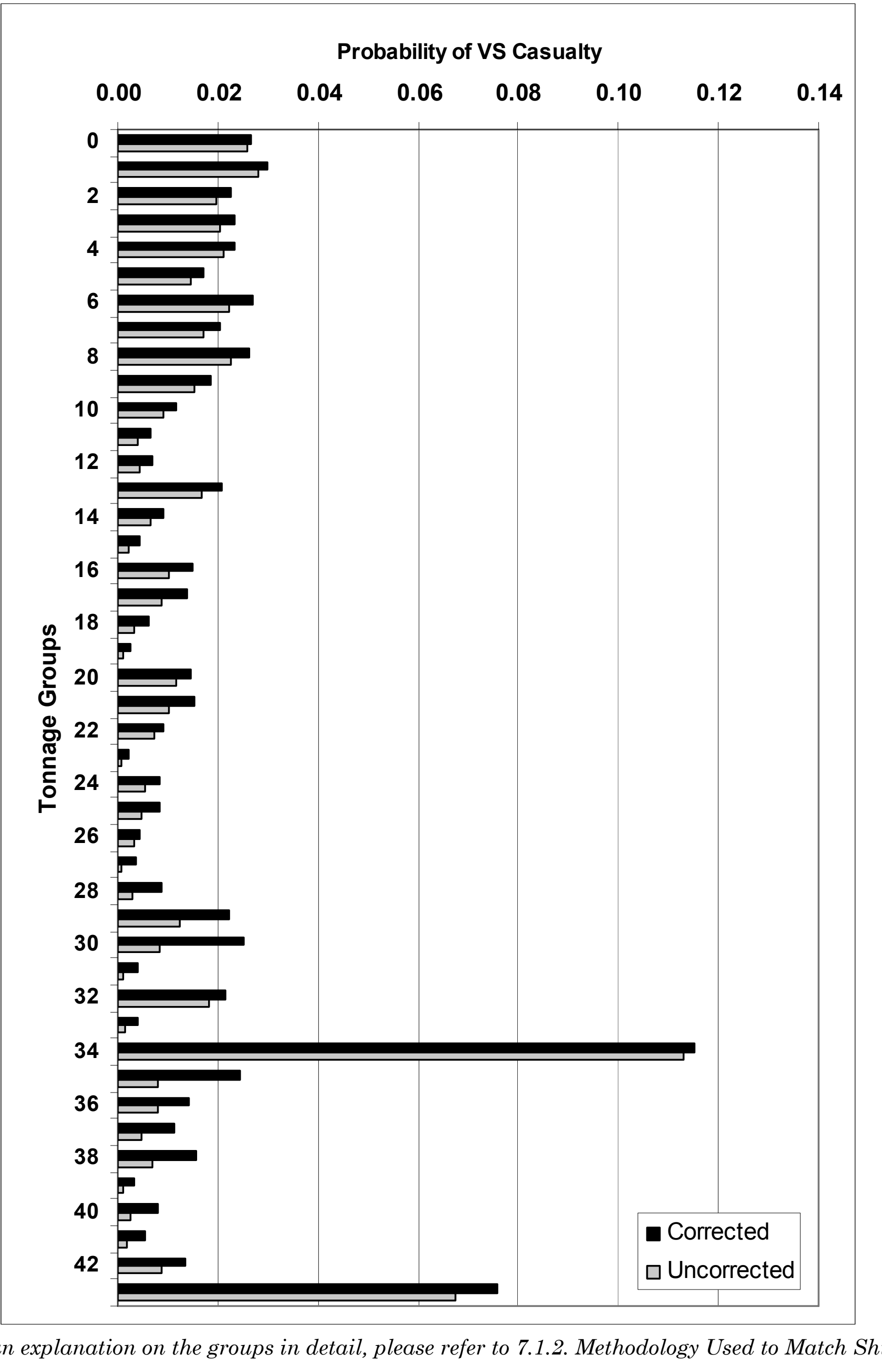
please refer to http://hdl.handle.net/1765/7913

Appendix 19: Estimation Results of Greene Model, Very Serious Casualties

please refer to http://hdl.handle.net/1765/7913

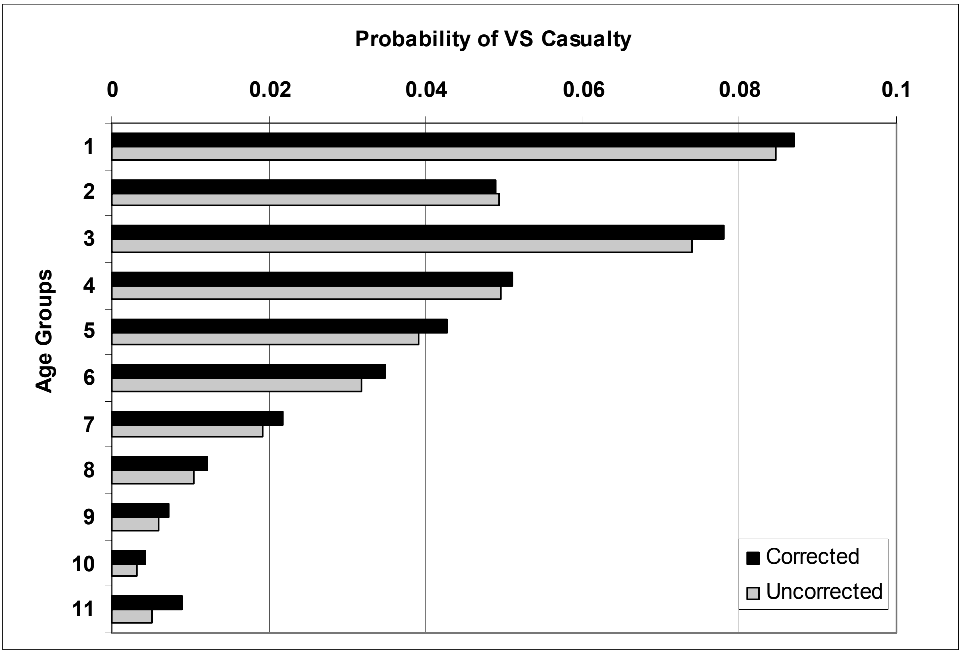
Appendix 20: Average Probabilities of Corrected versus Uncorrected Model

Tonnage Groups



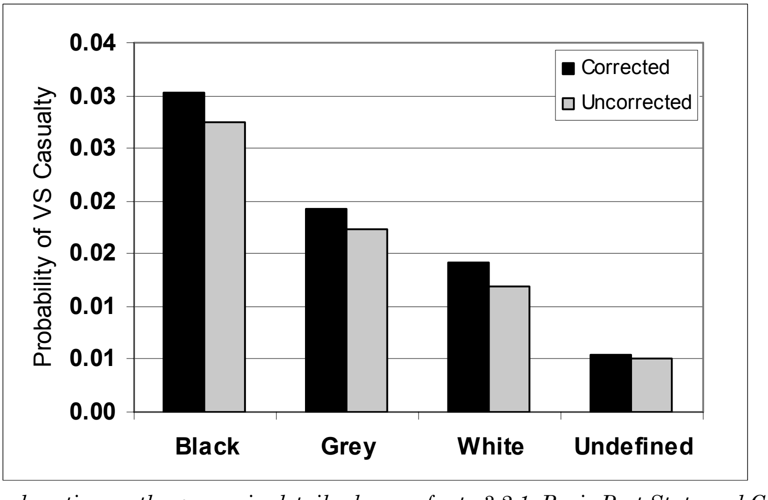
For an explanation on the groups in detail, please refer to 7.1.2. Methodology Used to Match Ships

Age Groups



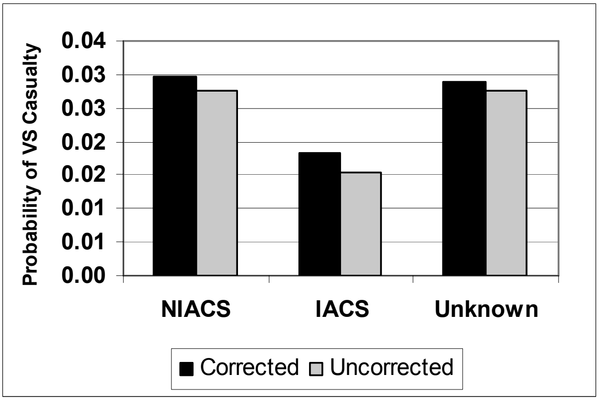
For an explanation on the groups in detail, please refer to 7.1.2. Methodology Used to Match Ships

Flag States Groups



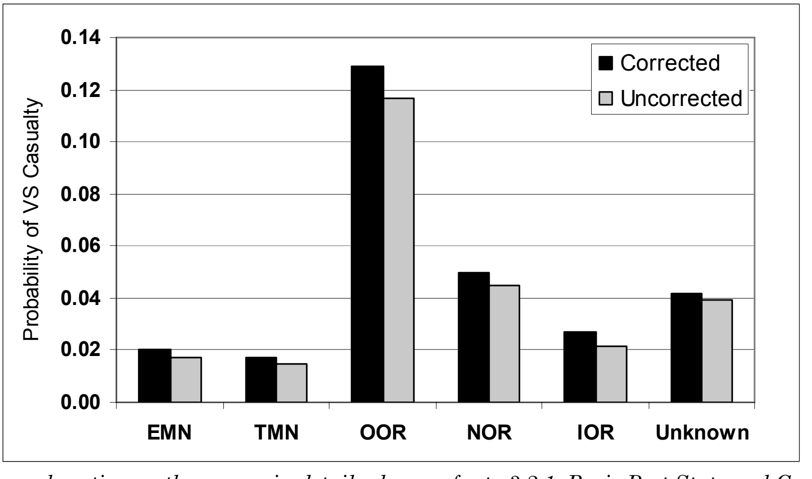
For an explanation on the groups in detail, please refer to 3.2.1. Basic Port State and Casualty Variables

Classification Society Groups



For an explanation on the groups in detail, please refer to 3.2.1. Basic Port State and Casualty Variables

Ownership Groups



For an explanation on the groups in detail, please refer to 3.2.1. Basic Port State and Casualty Variables

Appendix 21: Results of Regression: Very Serious Casualties

please refer to http://hdl.handle.net/1765/7913

Appendix 22: Results of Regression: Serious Casualties

please refer to http://hdl.handle.net/1765/7913

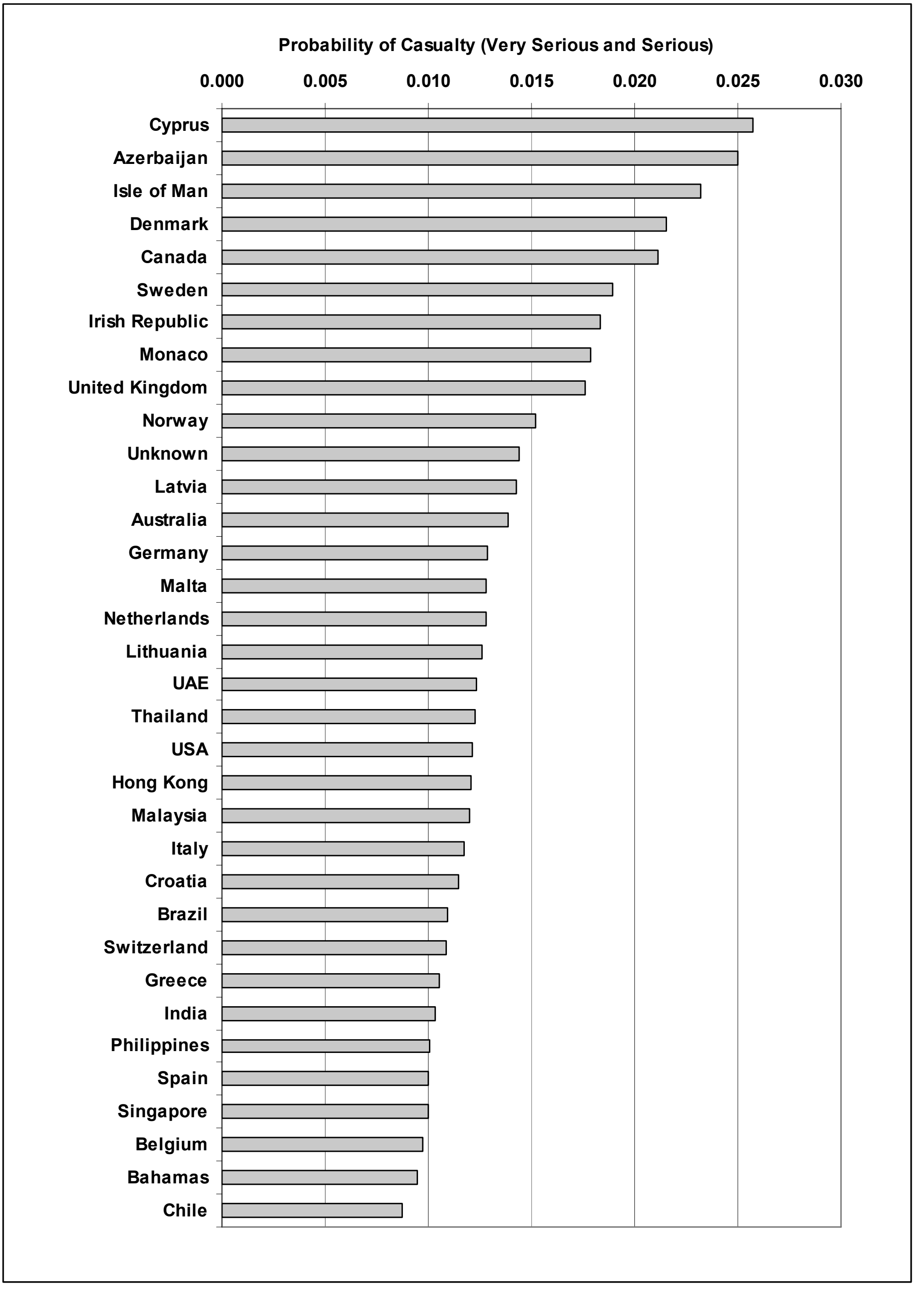
Appendix 23: Results of Regressions: Less Serious Casualties

please refer to http://hdl.handle.net/1765/7913

Appendix 24: Results of Regression: Fishing Fleet (above 400gt)

please refer to http://hdl.handle.net/1765/7913

Appendix 25: Probability of Casualty per DoC Country of Residence



Appendix 26: LM-Test Type I (Very Serious) and Type II Models

please refer to http://hdl.handle.net/1765/7913

Appendix 27: Matching Models: Type I Models

please refer to http://hdl.handle.net/1765/7913

Appendix 28: Matching Models: Type II Model

please refer to http://hdl.handle.net/1765/7913

Appendix 29: LM Test: Type III Models

please refer to http://hdl.handle.net/1765/7913

Appendix 30: Matching Models: Type III Models

please refer to http://hdl.handle.net/1765/7913

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The Econometrics of Maritime Safety

Recommendations to Enhance Safety at Sea

The maritime industry is characterized by a heavy legal framework based on international law with limited legal enforcement possibilities in case of non compliance. This creates loopholes and distortion to competition due to the existence of a market of substandard ships. The lack of trust in the industry has created a playground for inspections on certain ship types including considerable amount of industry driven inspections. This thesis is based on a unique dataset of 183,000 port state control inspections and 11,000 casualties from various sources in order to identify areas for improvement in the safety system, in particular port state control. Two areas of potential improvement have been identified: 1) the targeting of ships for inspections and 2) the inspections and follow up on deficiencies itself. The effect of port state control inspections towards the probability of casualty can be measured for very serious casualties but not for serious and less serious casualties. While key figures on deficiencies and detentions vary accordingly across the regimes, the differences towards the probability of detention is merely reflected by the differences in port states and the treatment of deficiencies and not necessarily by age, size, flag, class or owner. The classic variables such as ship type, age, size, flag, the classification society, deficiencies found in prior inspections and detention are all valid variables for targeting sub-standard ships but flag is only one variable out of many variables that can be used to target sub-standard ships. Targeting on combined inspection and ship particular data including information about change of ownership, class withdrawal, change of class and vetting inspections can further enhance targeting of vessels. The probability of casualty either per seriousness of casualty or casualty first event also revealed three areas of interest – the ISM code, ship and cargo operations and machinery and equipment which are the main areas that have been identified in order to decrease the probability of a casualty.

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