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The significance of main vessel characteristics in  
the detection of Ballast Water Deficiencies by the  
Port State Control

By

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## **Abstarct**

Shipping is a crucial part of the economy that contributes to the global trade of goods. Ballast water has been an essential factor for the stability of ships but also under investigation for causing environmental issues. The exchange of ballast water prior to the loading operations of vessels, has caused the introduction of non-indigenous species to new ecosystems. The consequences have an effect not only on the environment but also on human health. This lead to the formation of the International Convention for the Control and Management of Ships' Ballast Water and Sediments which was adopted in 2004.

The highly anticipated enforcement of the convention began on 09/09/2017, after the requirements for its ratification were fulfilled 12 months earlier, with Finland becoming the newest member state. The ratification has validated the application of the convention's D-2 regulation which requires from all vessels to install a verified BWMS. Yet, the regulation has been in full effect since 2004. Responsible for the compliance of all international conventions, including the BWMC after its ratification, is the Port State Control.

This research will specifically focus on the analysis of ballast water deficiencies detected by the member states of the Paris MoU. The aim will be to identify the main deficiencies and determine the likelihood of them to occur, given the main vessel characteristics. The total number of deficiencies recorded since the enforcement of the convention will be specified in terms of age, type and size. These will be the variables to the Event Tree Analysis that will be performed on each deficiency to show if there is any effect on deficiency detection. Final results will also be related to the requirements that Paris MoU has set for the determination of High Risk Ships (HRS).

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## **List of Abbreviations**

AMS: Alternate Management Systems

BWE: Ballast Water Exchange

BWM: Ballast Water Management

BWMC: Ballast Water Management Convention

BWMP: Ballast Water Management Plan

BWMS: Ballast Water Management Systems

BWRB: Ballast Water Record Book

BWTS: Ballast Water Treatment Systems

ETA: Event Tree Analysis

FOC: Flags Of Convenience

GT: Gross Tonnage

HRS: High Risk Ships

ILO: International Labour Organization

IMO: International Maritime Organization

LRS: Low Risk Ships

MoU: Memoranda of Understanding

MEPC: Marine Environment Protection Committee

NIS: Non-Indigenous Species

NOA: Notice of Arrival

PSC: Port State Control

PSCO: Port State Control Officer

RO: Recognised Organisation

UNCLOS: United Nations Convention on the Law of the Sea

USCG: United States Coast Guard

## **Chapter 1. Introduction**

### ***1.1 Research Background***

The rapid development of trade has been a vital factor for the transportation immigrant sea species between territories. This is caused by the process of ballast water management of the vessels. Ballast water is an essential aspect for the navigation of vessels, regardless of the type. Vessels are equipped with specific tanks that are responsible for their stability, balance and trim. Every year, more than 10 billion tons of ballast water are transferred globally. Despite its necessity in shipping, ballast water is also connected to the immigration of micro sea species to new territories. Those invasive species, mostly consisted of phytoplankton and zooplanktons, are microorganisms that can have a negative impact on their new ecosystem environment. The introduction of non-indigenous species can cause numerous consequences, like the decline of fishing industries and affecting the domestic food chain (Satir, 2014).

With regard to those speculations, the International Maritime Organization (IMO) proceeded in 2004 to the establishment of the “International Convention for the Control and Management of Ships' Ballast Water and Sediments”. The scope of the convention was to prevent the transfer of invasive species to new environments. As trade was developing and expanding rapidly, the effect of ballast water increased at the members of IMO (IMO, 2018). This provoked IMO in the adoption of the convention, given the threat of potential further expansion of this phenomenon. Until 2017, the convention obliged ship-owners to exchange ballast water under certain conditions, in accordance to the D-1 regulation of the convention. The D-2 regulation regarding the performance standards was not a mandatory provision so far, yet since September the convention has been put into force implying that the regulation should also be satisfied.

The effect of the convention will affect port regulations as well. Its ratification will require inspections by the port state in order to determine whether a vessel is in accordance with the regulations of the convention. If Port State Control (PSC) has determined that a vessel is not in compliance with the convention, it will be charged with deficiencies that vary on the misconduct or negligence of the owner. Aim of the PSC is to ensure a sustainable development for shipping, in accordance to international regulations. Port state has gained increased responsibilities over the past years, as efforts to improve environmental compliance and the condition of working environments became more important. Inspections are made based on criteria that the port state has established, regarding the selection of vessels inspected. This way, a priority list can be created for each port regarding incoming vessels, indicating the necessity for inspection for some vessel. Any vessel failing to reach the requirements, is liable for a detention by the port authority inspected (Li, 2002).

In order to improve the performance and organisation of port state control, the United Nations proceeded in forming regional agreements between countries, known as The Memorandum of Understanding (MoU). Through the platform of an MoU, it is possible for vessels with sub-performance indications to be monitored and more regularly inspected. Until today, various MoUs have been established (Paris, Tokyo, and

Mediterranean) while other countries have their independent systems, like US which inspections are made and recorded by the Coast Guard.

The enforcement of the convention will alter the responsibilities of Port State Control. It will definitely burden the responsibilities for Port State Control Officers (PSCO) by bearing in mind the performance standards of the vessels in addition to the exchange requirements. The purpose of this study is to acknowledge the main deficiencies awarded to vessels from the different regimes and identify whether there is a sequence between the nature of the deficiency and the characteristics of the vessel (Xu, 2001).

## ***1.2 Problem Statement and Research Objectives***

Port inspections are a natural procedure at ports in order for the authorities to determine the compatibility of vessels with international conventions. Different port state controls have different criteria for inspection, however all MoUs and port regimes are in accordance with the 2004 BWM convention. The question is what those criteria are and how different regimes decide upon inspection targets. Through this research, the author will try to analyse the results acquired from vessel performance, recorded particularly at the port regimes of the United States of America and Europe and identify relations between the deficiencies detected of the regimes in regards to main characteristics of the vessel, namely age, type and flag state registration. A very common measure that many ship owning companies rely on, is to register their vessel into third-flagged countries due to the lenient regulations regarding taxation and convention compliance rules. While convenient flags can secure less restrictive law obligations to owners, the risk for misconducting safety and environmental standards increases. Furthermore, the result from deficiencies gathered shall be evaluated based on the Ballast Water requirements applying to regions (ABS, 2016).

Moreover, it would be interesting to investigate the impact of the ratification of the D-2 regulation to the management of ballast water inspections by the port state. Even though the convention was adopted in 2004, only very recently was put into force, enhancing the known responsibilities for port state authorities. For this reason, there is limited available literature as not many studies have yet opted to focus on the specific subject. The outcome of the analysis on the collected data, will help mark the most common deficiencies applied and consider the reasons why owners neglect some of their requested tasks. An effort will be made to propose future suggestions, so that owners can secure a good cooperation with the correspondent port state. Vessels constitute the most valuable assets for owners, while the possibility of a deficiency reward and subsequently a detention could yield financial losses and severely damage the “reputation” of the vessel.

Detained vessels at one MoU are also considered detainable to other MoUs, so this is an extra reason why owners need to protect their vessels from deficiencies and not allow them to become liable to detentions. With the enforcement of the convention already applying since September of 2017, port regimes have been keeping records related to BWM since then. The outcome of the research shall increase the awareness of owners regarding the management of ballast water at their vessels and propose solutions for better and more sustainable management. In order to achieve that objective, it is essential for a research question to be formed:

*“How is ballast water controlled by the port state and what changes will arise from the enforcement of the 2004 IMO Convention?”*

The main research question shall help in understanding the procedure followed by port state in the BWM inspections and the way deficiencies are charged in case of a misconduct. Consequently, we will try to interpret results from the total deficiency records and draw conclusions regarding any relationship between the nature of the deficiencies and the characteristics of a vessel. To support the scope of the main questions, the following sub-questions will have to be answered:

- i. What regulations are implied after the enforcement of the convention?
- ii. What are the key differences between the active MoUs in terms of vessel targeting and Ballast Water monitoring?
- iii. How the ratification of the convention does affects the awareness regarding the prevention of deficiencies?
- iv. To what extend are port states deficiencies more likely to be awarded according to vessel differentiation?

### **1.3 Thesis Structure**

It is fundamental for every research to be appropriately segregated in order for the author to reach his objective. The second and third chapter of this research will cover the available published literature related to the topic. More specifically, it shall include the importance of ballast water and the impact of BWM omission acts. In addition, all respective legislations and regulations regarding the management of ballast water shall be highlighted, especially the changes occurred due to the convention enforcement.

Moving on with chapter 4, there will be presented information and speculations regarding the PSC. As the focus of the research is based on the Paris MoU, Tokyo MoU and USCG, the different characteristics of the three memoranda will be presented. The methodology used to complete this study will be outlined in the 5<sup>th</sup> chapter. It will be explained how the conceptual framework for this research was formed and what the writer wants to achieve. Given that a quantitative analysis will be performed on the data collected, in the same chapter it will be crucial to present which the variables are and what can be established through their relationship. A decision tree model will be used for the data analysis.

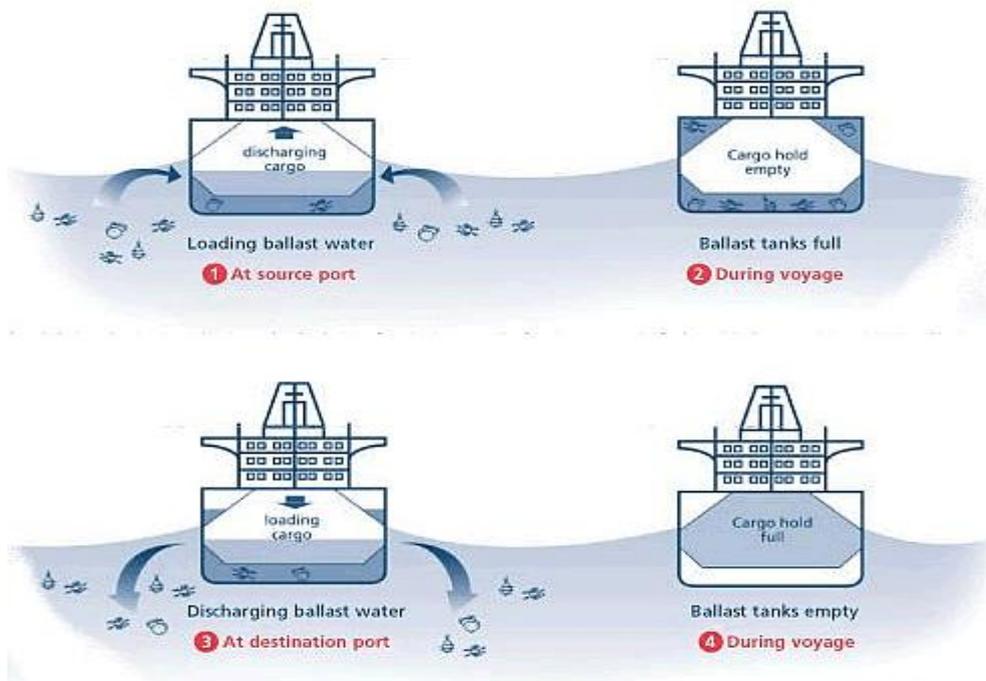
In chapter 6, the analysis of the probability tree between the variables will be presented. After this analysis has been completed, we will interpret the results and will identify to what extend those variables can determine the type of ballast water deficiencies. The collection of data, primarily drawn from the Paris MoU, will also allow us to make comparisons between them and determine what differences are observed in terms of dealing with BWM deficiencies of other MoUs.

Finally, chapter 7 will draw the conclusions from the whole research and provide further recommendations.

## Chapter 2. Literature Review

### 2.1 Ballast Water

Any solid material used for the stabilization and trim of a vessel is defined as ballast. Those materials add weight to the vessel and thus increase its draft, within acceptable pressure limitations for the vessel's hulls. Vessels originally placed solid and heavy objects like rocks as ballast materials when a vessel was partially loaded or not loaded at all. During the 19<sup>th</sup> century, people first experienced a change by replacing those materials with harbor water. This had made ballast water operations much more efficient and with quicker replacement. During the 1950s, ballast became more globally known and was also established as an important aspect in the design of the vessels. The graph below displays the procedure of ballast water exchange between the open sea and the ballast water tanks (Satir, 2014).



Picture 1: Ballast Water Exchange (Longshoreshippingnews.com, 2011)

The management of ballast water is challenging for all vessels. According to (Endresen et al., 2004), every vessel's characteristics determines the total volume of ballast water that it requires to maintain stable on voyage. Ballast water tanks differ per vessel type and are designed based on the maximum cargo load factor of each type. The management of ballast water tanks is adversely related to the level of cargo

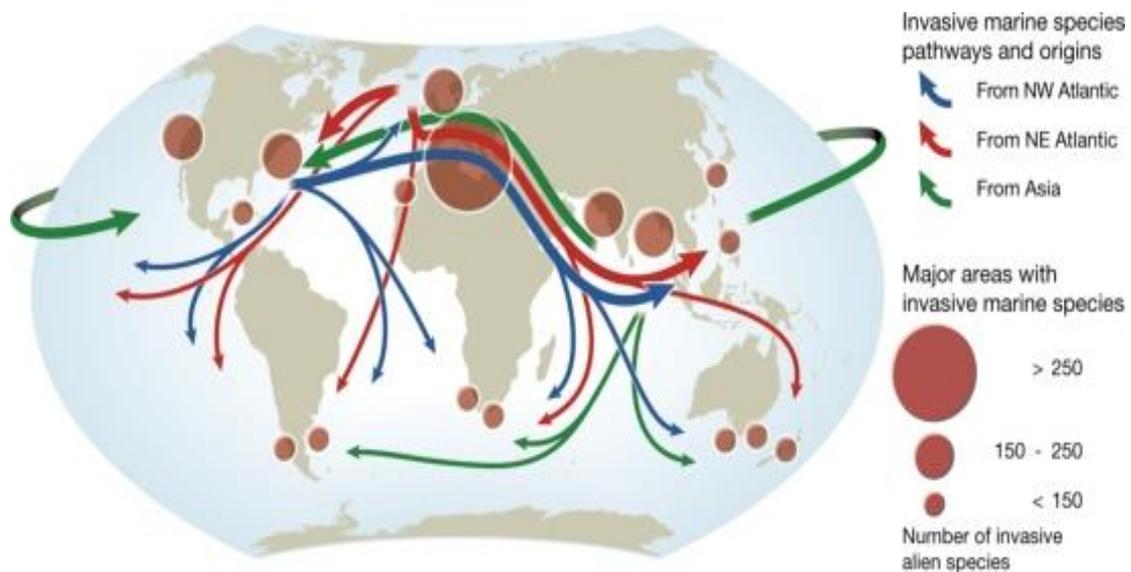
that a vessel is loaded. While a vessel is discharging cargo, the tanks of ballast water are filled with sea water. This way the stabilization of the vessel is achieved when the vessel is laden and required extra weight. On the loading port, the water will have to be discharged in order for the vessel to safely load the cargo assigned. If the vessel is laden, there is no need for the presence of ballast water to the tanks and will not be needed until the vessel unloads its cargo to the connecting port.

The challenges are many for the safe and sustainable ballast water performance by vessels. More importantly, the introduction of non-indigenous species has been a major concern. The import of ballast water to tanks can be a path for those species to transport from one territory to another. For this reason also, IMO adopted the BWM convention for the safe exchange of ballast water. IMO aims to prevent the 'flushing' of the used ballast water at the sea. Zhang and Dickman (1999), indicated that the area of exchange is also an important factor in the overall impact of ballast water. Species discharged at open-ocean have a higher possibility of survival, mainly due to the existence of nutritious substances for those species. This allows them to adapt more easily in their new environments, compared to mid-ocean exchange, where survivability of those species is more unpredictable.

## **2.2 Invasive Species**

The most potentially increasing issue with ballast water management is the presence of different invasive species within the sea water ballasted. The first suspicions were risen regarding the transportation of living microorganisms via the ballast water tanks to new territories (Satir, 2014). According to Bailey (2015), one of the most characteristic example is the introduction of the Comb Jelly (*Mnemiopsis leydei*) into the territories of the Black and Azov seas. A large amount of Comb Jellies were released in the sea through the BWE, and these consumed a large percentage of the zooplanktons of the area. The local fish population found it increasingly more difficult to feed in this area due to the reduced zooplanktons, which is their main form of nutrition. This resulted in a gradual deterioration of the local fishing industry as the fish population in those seas was diminishing. Another similar incident is the identification of the *juvenile lionfish*, at the coast of USA. The lionfish reached the States through the ballast water exchange and has now fully adapted at the US coastal waters. The US, along with Western Europe and Japan, hold the highest conciseness of immigrated species due to the expansion of trade (Padilla and Williams, 2004).

Many similar incidents have been recorded in cities that are situated at the beachfront worldwide. As it can be seen from the map below, the main trading routes for shipping markets seem to have an impact in expanding transportation of marine species to unfamiliar environments. Ballast water has been expanding proportionally to the trade expansion and thus the introduction of new invasive species vary. They gain access to the ballast tanks of the vessels during the exchange and have the ability to remain viable in the tanks for periods as long as several months. Ballast water has always been an important aspect that shipping was relying on for its stability on water when not laden. Even though it is slightly possible that invasive alien species (IAS) can adapt with no consequences to their new environment, the development of technology enabled the findings of solutions for the matter (David and Gollasch, 2014).



Map 1: Major Pathways of Marine Invaders (Dabrownstein.com, 2013)

Nowadays, ballast water treatment systems (BWTS) have been developed with the help of technology and are effective in dealing with living organisms entering the ballast tanks. Systems are installed on vessels and through different techniques seek to remove organisms. Those techniques include mainly mechanical, chemical and physical treatment. Each treatment is suitable for different type of species and selection of a suitable system by the owner should be in accordance with the type of the vessel and its trading patterns. The financial investment including installation, maintenance and operational costs is also a major concern for ship-owners for the system selection and installation (Satir, 2014; Jee and Lee, 2017). IMO reacted to this phenomenon with the adoption of the convention for the management of ballast water and sediments in 2004. David et al, performed in 2007 an analysis of the convention including all of its important requirements, risks, sampling tools and provisions in order for the convention to be official put into force. The only thing remaining is the ratification of the convention.

### **2.3 Port State Monitoring**

Once the convention was ratified, the authority responsible for maintaining its compliance is the port state control. Regardless of flag classification, all vessels are liable for inspections. In order for the PSC to efficiently identify non-compliers, it is stated in various studies that specific flag registries are more liable for inspection. According to Fan, Luo and Yin (2014), supervision tends to be stricter with third countries registries. Due to the lenient legislation applied at those states, there is a greater chance for respective owners to neglect the requirements regarding ballast

water management. Such flags are known as flags of convenience (FOC). With port state being responsible to monitor their activities, the overall number of incidents caused by vessels under a FOC is significantly reduced. The study showed that there is a relation between port state inspections and the flag registry of vessels. In addition, the economic and social stability of a country are also considerable parameters upon vessel targeting. Finally, it was carried out by the models tested that age and type of a vessel experience a higher inspection rate is what drives owners to switch to FOC. Other studies have also been made to determine the impact of flag classification.

A different research was performed by Randic, Matika and Moznik (2015). Given the need for inspection by the port state in order to maintain the safety at sea, the authors examined the reasons or recommendations that vessels do not comply with the regulations. Those recommendations are known as deficiencies and if detected PSC the vessel then has to deal with the deficiency in order to continue its navigation (Xu, 2001). This time, deficiencies awarded by the PSC were analysed through a SWOT analysis. This allowed Randic et al., to interpret the deficiencies both in terms of internal and external environment. Two were the main outcomes of the research. First, improvements in the internal environment could be performed by educating and increasing the awareness of the crew of the vessels. The training of seafarers is becoming less sufficient for the demands of PSC, which is something that can definitely be developed. Yet, a big share of the seafarers have little or no educational background which increases the difficulties of familiarisation with the systems of a vessel. Second outcome that the previous researches mention is the age of the ship. Again, older vessels tend to have a greater rate of deficiencies compared to younger vessels.

Deficiency reward is the main penalty that the port state can award to non-compliant vessels. Besides ballast water management, inspections and deficiencies have become a core responsibility for them. In coordination with the datasets of established MOUs, Kim in his research attempted to find a correlation between the accidents occurring at sea, the impact of human error and the detention awarded by the port state (2005). Even though there was no significant relationship between the variables, it was found that accident rates are related to the number of PSC inspections. The majority of studies concern the overall impact of port state control and inspections to vessels. In this study we will investigate the deficiencies awarded to vessels from the perspective of ballast water management, under the effect of the IMO convention. Yang (2017), completed a similar study, however focusing more in the labor department and the effect of the ILO convention.

There has been a wide range of previous studies regarding the relation between the main ship particulars and the PSC inspection selection. Knapp and Franses (2007), tried to identify ways of making more efficient the inspections of PSC in terms of targeting more risky vessels. To achieve that, they recalled on PSC data in order to determine the probability of casualties to be drawn based on the results of the inspections. Penalised ships were classified by their characteristics and were used as variables in casualty models. Age, size in GT and specifically general cargo type vessels showed the most serious connection. Regarding gross tonnage, Heij et al. (2011) performed a similar research with upper scope evaluating the performance of PSC through the results from their inspections.

Finally, Cariou, Wolf and Mehia Jr. decided to investigate the effectiveness of the PSC inspections. The outcome presented deficiencies collected over a specific period of time and their likelihood to be spotted during a PSC inspection (2008). Accidents

occurring at sea will always be a major concern and subject for further research. Port state has been established to minimize the existence of risky vessels, and through the inspections they are able to identify the reasons why a vessel can face various dangerous incidents. Raiyan et al., tried to identify all the realistic possible events that could lead to marine accidents at Bangladesh. In order to achieve this, they performed an Event Tree Analysis (ETA) for all possible paths to be identified (2017). A similar analysis was also performed by Tzannatos and Kokotos (2009), this time with data from the Greek PSC used in a classification tree analysis.

## Chapter 3. Ballast Water Management Convention (BWMC 2004)

In this chapter, information regarding the BWMC will be provided to the reader. As a start, the regulations that applied under the adoption of the convention will be presented.

### 3.1 Adoption in 2004

Ballast water management is considered today one of the key aspects in order to achieve a more sustainable shipping services sector. Yet, the legislation regarding the management of ballast water has been lenient despite its importance. United Nations wanted to prevent the biodiversity problems caused by invasive species through ballast water and proceeded in forming the “International Convention for the Control and Management of Ships' Ballast Water and Sediments” in 2004. The principal scope of the convention is “*prevention, minimization and ultimate elimination of the transfer of Harmful Aquatic Organisms and Pathogen*” (IMO Annex, 2004).

As the rate of invasive species was constantly rising, the formation of the convention was essential as it is considered that the problem has not yet reached its peak. What the convention achieved primarily has been to create a framework within which all contracting states could monitor the ballast water exchange under the new legislation. The convention was adopted in 2004, but has not yet been put into force. This would require the approval of the convention by minimum 30 states representing at least 35% of the total gross tonnage. Once the above requirements are fulfilled, the convention will be put into force 12 months later. Even though there were more than 30 states that had already signed the convention in 2004, the lack in the total gross tonnage carriage resulted in only adopting the convention. It had been expected that by 2014 the ratification of the convention would have been completed. However, Fernandes et al. stated that during the October of 2014, 43 countries had signed its ratification representing though only 32.5 % of the global gross tonnage, meaning there was still a deficit of 2.5% (2016).

Still, the formation of a framework increased the awareness of ballast water management. In practice, the convention provided guidelines for vessels to be in compliance with the regulations. Section B of the annexes, indicates the requirements that all vessels should follow for the management of ballast water.

- **B-1 Regulation:** Requires the presence of a Ballast Water Management Plan (BWMP). The plan should be approved by the Administration and should have a description of all actions related to ballast water. Moreover, the master and crew must be familiar with the ballast water procedures and have completed the necessary training. Each BWMP is unique for each vessel.
- **B-2 Regulation:** This regulation indicates the necessity of a Ballast Water Record Book (BWRB) on board the vessel at all times. Inside, all ballast water related activities should be recorded and be available for inspection at any time. All BWRB should remain on board the vessel for 2 years after its last record.

- **B-3 Regulation:** Includes all specifications regarding the ballast water management for ships. Indicates under which standard the vessel will be ruled upon. Clarification is made through the year of construction and the size of its ballast water tank.

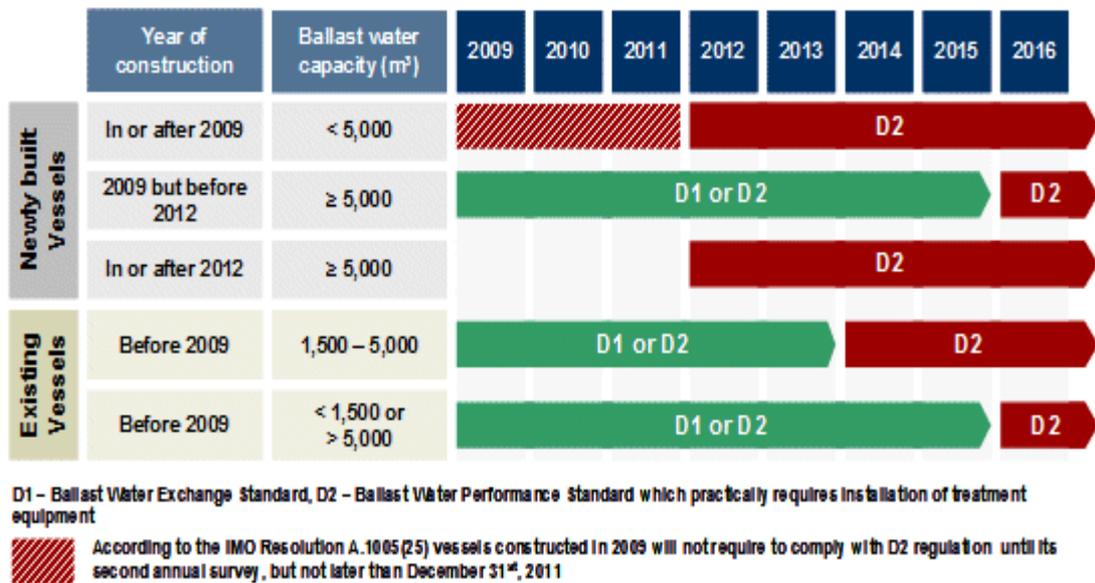


Figure 1: Timelines for compliance with the BWMC (Royan, 2010)

Other regulations also include guidelines regarding the safe exchange of ballast water (B-4 regulation) and sediments management (B-5 regulation). Those are the main regulations that apply for all member states, yet it is possible that some states have additional requirements. IMO should be informed in advance for independent state requirements and consequently approved. All vessels are subject to inspections and surveys conducted by the PSC. Such inspections should not at any purpose cause the delay of a vessel (IMO, 2018).

### 3.2 Performance Standards

Section D of the convention constitutes the guidelines of the standards that apply for the management of ballast water. Standards concern mainly the exchange and performance of ballast water.

#### 3.2.1 Standard Performance D-1

The D-1 regulation of the IMO convention is related to the exchange of ballast water. Purpose of the regulation is to reduce the number of invasive species that migrate to new environments. It instructs vessels to perform the exchange of ballast out in the

open seas. This way, any non-indigenous species will be in a reasonable distance from the coast, preventing these microorganisms to increase the biodiversity near coastal areas. It is also believed that there is a smaller percentage of survivability for those species once they are released in open sea. The standard is according to the B-4 regulations regarding exchange instructions. More specifically all vessels should exchange:

- 200 nautical miles away from the coast
- in a depth of 200 meters
- at least 95% of total volume carried

### 3.2.2 Standard Performance D-2

The requirements for the performance of ballast water management are outlined in the D-2 regulation. It is the second regulation that outlines the scope to dealing with the aquatic invasive species. The regulation provides a limitation to the maximum number of viable biota identified in a ballast water sample. In order for a vessel to be able to discharge under the regulation, ballast water should not exceed the microbe concentrations which are presented below:

Organism and Size	Concentration
Any Organism $\geq 50$ microns ( $5 \times 10^{-5}$ meter)	10 per meter <sup>3</sup>
Any Organism $10 \geq 50$ microns	10 per milliliter (10,000,000 per meter <sup>3</sup> )
<b>Microbes</b>	
<i>Vibrio Cholerae</i> (Cholera)	1 colony forming unit (cfu) per 100 milliliters or 1 cfu per gram of zooplankton sample
<i>Escherichia coli</i> (E. Coli)	250 cfu per 100 milliliters
<i>Enterococci</i> (intestinal)	100 cfu per 100 milliliters

Figure 2: Indicator of microbe concentrations (Lindholm, 2018)

Considerations upon the selection of microorganisms was determined upon their impact to human health. Fundamental condition for those restrictions to apply is only through the enforcement of the convention. In addition, it forces owners to install a BWTS in order to stay within range of the IMO concentration restrictions. Those BWTS must be approved by the administration prior to installation. Once approved, there are different techniques applicable for maintaining the restrictions.

### 3.2.3 Standard Performance D-3 & D-4

Section D of the Annex, is also composed with regulations D-3 and D-4. The requirements for BWMS are outlined in the D-3 regulation. In order for a BWMS to be applicable, it must first be approved by the administration. Ships that have BWMS not approved will be liable for deficiencies. On April 2018, MEPC adopted guidelines for the efficient installation and usage of the systems, known as the BWMS Code.

D-4 outlines the technologies applied to the BWMS. The installation of BWMS is in accordance with the D-2 regulation. Purpose of their existence is to maintain compliance with the regulation. Both regulations shall enter in force 5 years after the ratification of the convention. It will be a 5-year experience period for owners and crew in order to familiarise with the technologies of the system.

### **3.3 Enforcement of the Convention**

As already mentioned, the fact that the convention was only adopted and not put in force, significantly restricted its effect. At last, on September 9 2016, Finland became the 52 member signing the ratification of the convention with a total of 35.14% of the total gross tonnage being in accordance with the convention. As the minimum limit for the gross tonnage representation was exceeded, the 12-month countdown for the enforcement of the convention had begun (Lindholm, 2018).

On the 9<sup>th</sup> of September 2017, the IMO ballast water management convention was put into force officially. The enforcement will bring numerous changes in the management of ballast water. To begin with, all vessels must be equipped with an approved BWTS. All vessels that are about to be constructed after the ratifications must follow the D-2 performance standard. For vessels already built, it has been agreed that there will be an extension in the application of the convention. The extension is linked with the International Oil Pollution Prevention Certificate (IOPPC) renewal survey<sup>1</sup>. With the agreement of the Marine Environmental Protection Committee (MEPC), a new timeline was created for the implementation of the standards.

There will be allowed two five-year renewal surveys for all existing vessels. First one for vessels with a renewal survey two years after the ratification (2017-2019). If previous renewal surveys by IOPPC had been performed three years prior to the ratification of the convention [8/9/2014-8/9/2017], then vessels are subject to the D-2 performance standard. For vessels that had their renewal before 8/9/2014, compliance with the regulation shall apply after a survey renewal is performed. Existing vessels will be allowed an extension of 5 years to renew their survey and allow them to prepare for the requirements. This may be a new and challenging experience for many owners that will have to decide upon the most suitable BWTS.

The second renewal service is about vessels with renewal surveys after or on the September 8<sup>th</sup> 2019. This affects all new buildings as well as vessels that had not had a renewal survey for at least five years. Targeted vessels must comply with all the requirements of the performance standards as stated in regulation D-2. The goal for

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<sup>1</sup> Survey of the IOPPC is under compliance with Annex I of MARPOL

the Administration after the end of the second five-year period (2024) is that all ships will have met the D-2 standards (Smedley, 2017).

## **Chapter 4. Port State Control**

### ***4.2 Legal Provision***

The concept of PSC has been included nowadays in many conventions and its practice is performed globally. The legal ground covering IMO and ILO conventions has allowed port state authorities to make inspections to vessels and testify whether the regulations of those conventions are met by incoming vessels. Besides the BWMC, port state has the authority to examine compliance with other conventions as well.

#### **4.2.1 SOLAS 74**

SOLAS 74 stands for the International convention for the Safety Of Life At Sea, first adopted by IMO in 1914 as a result of the Titanic incident two years earlier. Scope of the convention is to provide all floating vessels with safety standards in order to prevent life-threatening accidents at sea. After various amendments, the 1974 conference resolutions have been agreed by 100 states representing the 95% of the total tonnage share at the period. All non-parties convention should comply with Article II of the SOLAS 78 protocol, which is incorporated to the 1974 convention (Hare, 1997).

According to Chapter XI and regulation 4 of the convention, PSC has the authority to inspect the familiarity of crew and compliance of the vessel to the safety procedures as imposed to the convention. Certifications issued and validated by the flag state indicate that a vessel comply with the requirements.

#### **4.2.2 ISM Code**

The International Safety Management (ISM) Code entered into force as part of Chapter XI of the SOLAS 1998 protocol by IMO. Aim of the code is to provide with standards for safety management and prevent pollution through enhanced vessel operations. The most important goal is to minimize accidents caused by human error that lead to environmental pollution incidents. It encourages companies to adapt, within their working environment, a Safety Management System (SMS) which will present rules and guidance to secure safety at sea.

As ISM Code is included within Chapter IX of SOLAS amendment protocol of 1998, PSC must ensue that the vessel is in compliance with the code. Familiarization of the code by the seafarers is one of the most important requirements of the code. Crewmembers should be fully aware of the code's requirements and should be prepared to pass any drill requested by the port state control officer (PSCO).

### **4.1 Background and Foundation**

The body responsible for the monitoring of ballast water management and sediment is the Port State Control (PSC). Besides ballast water and its harmful impact, the PSC was established to ensure that environmental compliance is maintained by all states.

It was initially established by IMO in 1982. The catastrophic accidents that occurred at sea during the 70s and 80s definitely increased the awareness of the community. The formation of conventions by the UN agencies, such as IMO and ILO, was a first step for safety at sea. However, it was essential that those regulations were followed by the flag states. States that have signed the approval of a convention, should also ensure that vessels operating under their state flag complied with those regulations. Responsibility relied to all flag states to check that all registered vessels were equipped appropriately to meet the existed regulations (Xu, 2001).

Yet, not all flag states were in accordance with the international pollution and safety regulations. Certain flags, known as flags of convenience (FOC), are called those that are relatively lenient in terms of regulations, having not signed proposed conventions. Consequently, this prevents the enforcement of the conventions resolutions by these vessels. As registries in FOC increased, and still remains popular for many owners, the reason for establishing PSC by IMO was a way to monitor the performance of the flag states. Port state would act as a back-up system monitoring that flag states follow the international standards. The lack of performance and the rapid expansion of FOC resulted in the formation of PSC in 1982. Moreover, as trade expanded accordingly, the same year in order to achieve a more efficient controlling over vessels, some regional agreements on PSC (Memorandums of Understanding – MoUs) were formed. The first one was in the Paris MoU in 1982 and then 97 others followed. The division was made in a way that all navigable coasts would have been covered and effectively monitored (Ketchum, 2000).

Given the definition as provided by IMO, port state control “is the inspection of foreign ships in national ports to verify that the condition of the ship and its equipment comply with the requirements of international regulations and that the ship is manned and operated in compliance with these rules” (2018). Due to the negligence of owners, who are primarily responsible for the safety of the vessel, the adoption of port state inspections was established in 1995. The formation of the Convention on the Law of the Sea by the United Nations (UNCLOS) was fundamental in the formation of PSC. Article 216 of the convention, indicates that a port state has the jurisdiction to inspect vessels if necessary. To support their mechanism, a couple of years later IMO and MEPC.26<sup>2</sup> published guidelines that indicated how a vessel can successfully pass the port state inspections. In order for vessels to pass the inspections, they should comply with the requirements and this can be proved through certifications, established at the flag state of the vessel. Any vessel with a certification granted, will indicate that the vessel is in full compliance with the obligations of the conventions. A flag state is responsible for issuing certificates for all vessels under the flag that are capable of complying with the requirements. Moreover, all flagged vessels will have a priority in inspection, compared to foreign vessels. The following subchapter will provide with all legal ground covered by the PSC (Xu, 2001; Sage, 2005).

#### 4.2.3 MAPOL 73/78

Accidents at sea have always been a major concern for the committee due to the consequences to the environment. On 1973, IMO proceeded in the adoption of the International Convention on Prevention of Marine Pollution. The convention has been widely approved similarly to the SOLAS 74 convention. The convention is composed by 6 Annexes, which relate to different sea pollutant cargoes as well as the

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<sup>2</sup> Marine Environmental Protection Committee Resolution Number 26

management of garbage and sewage. The most recent addition included prevention of air pollution as well<sup>3</sup>. The first two annexes regarding, pollution by oil (Annex I) and pollution by Noxious Bulk substances, were firstly put into force in 1978.

Upon a port state inspection, crew must be fully aware of the vessel's garbage and sewage management. Scope of the convention is to prevent both accidents and routine mistakes. In addition, the handling of dangerous goods according to the convention should be completed via safe operations with minimal exposure to the sea.

#### 4.2.4 STCW Convention

The International Convention on Standards of Training, Certification and Watch keeping for Seafarers was adopted by IMO in 1978. The purpose of the convention, was to provide with international standards for promoting safety at sea and environmental protection. The convention was put into force in April 1984. It provides with all the requirements regarding the training and Watch keeping of seafarers.

Any ship considered as not being compliant, may be required to be further inspected by the PSC. Under certain conditions, PSCO have clear ground to make more detailed inspections. This is when a vessel is grounded, involved in a collision or unsafe maneuver and possesses illegal cargo.. Inspections usually involves checking the equipment on board and testing drills on seafarers.

#### 4.2.5 STCW 95

Given the importance that IMO places on the seafarers' performance, the organisation proceeded into an amendment in 1995, in order to increase the impact of the convention. Under the new rules, if the port state has suspicions that a vessel is not trustworthy and does not fulfill the requirements, it can be called upon for a detailed inspection. This has been added as a fourth condition under which the port state will have clear ground to inspect the vessel.

Situations of possible "danger" are resulting into deficiencies by the port state. Unless the owner and crew manage to fix the problems concerning the officers, the ship can be detained as it will be considered as a danger to people and the environment. Officers should also check the performance of the crew on related drills and will have to verify the certification of the seafarers. According to Article X of the convention and regulation I/4, all seafarers must acquire a valid certificate issued by the state (Ozcayir, 2004).

#### 4.2.6 ILO 147

The well-being of seafarers as well their need for a safe labor environment was also major priority for the International Labor Organization (ILO). Seafarers, regardless under which flag the vessel operates, should be equally respected and not work under sub-standard conditions. In an effort to establish a safer working environment with no marine casualties, ILO adopted the Merchant Shipping (Minimum Standards) Convention in 1976. The convention was finally put into force at 1981 and includes

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<sup>3</sup> Annex VI (Entry into force: 2005)

other conventions issued by ILO, covering minimum age restrictions, medical condition, crew accommodation and injury benefits.

No. 147 contains minimum required standards for safety conditions on board. It applies to all commercial vessels, except sailing and fishing boats. ILO established the 1996 Protocol which included the approval of port state inspections to suspect vessels. Officers on board will examine the compliance of the convention to seafarers as mentioned in Annex I, section 7 of the convention (Ozcayir, 2004).

#### 4.2.7 Load Line Convention

The draft of a vessel is considered a great monitor of safety for vessels. Draft restrictions apply to all ports, with values depending on the berth's depth at each port. Overloading can cause increased stress on the hulls and have an impact on the vessel's stability. Weathertight and watertight integrity must also be monitored. For this reason, IMO adopted the Load Line (LL) Convention in 1966 and was put into force two years later. The application of freeboards as a form of limitation for the draught. Subdivision and damage stability calculations are used as provisions for defining the freeboard of a vessel.

The convention contains three Annexes. The first one indicates requirements for freeboards. It is important to mention that all vessels over 24 meters and 150 gross tonnage are under the rule of the convention. Annex II describes the zones and seasonal periods while the third refers to the certificates (International Load Line Certificate). PSCO must confirm of valid certificate issuing by governments upon inspections.

### **4.3 Regional Memoranda of Understanding (MoUs)**

The conventions established by IMO should be strictly followed by all signing states. They are responsible for their adaption and implementation by vessels floating under that flag state and should be applied as domestic laws. Yet, it has been noted that a number of flags exceeded in detentions and deficiencies as a result of neglecting the requirements of the conventions. This sub-performance is due to the lack of authorization in such countries to force their requirements.

This led IMO to the formation of the Paris MoU in 1982. Paris MoU was the first regional agreement signed representing the European countries and the Northern Atlantic area. The division into regional agreements was implemented in order for the organisation to better monitor the progress countries by region. Today, 7 additional MoUs have been agreed covering any navigable route. These will bring a balance to the demand at ports of the same region, while inspections by the PSC are expected to increase regarding information exchange and create global standards for everyone to follow. The project requires co-operation and strong cooperation from the governments' side to show commitment in improving the current condition, while further aid will be provided to developing countries in order to achieve the standards (Flag state implementation, 2010; Li and Zheng, 2008).

In this section, there will be a deeper analysis on the framework and structure of the three established MoUs. The first two are the most active MoUs, Paris and Tokyo.

Besides being established earlier of all, they are responsible for very busy areas. The third one is the United States Coast Guard. The US is not a member of the IMO and is relying on local legislation for environmental and social compliance, with the coast guard acting as the PSC. The focus of this study will be on how the PSC can adapt to the requirements of the BWM convention and how do the port state authorities monitor the ballast water related deficiencies.

#### 4.3.1 Paris MoU

The first regional agreement signed, as mentioned before, has been the Paris MoU. Prior to its formation, the North Sea states had signed the Hague Memoranda in order to comply with the ILO 147 convention in 1978. There were numerous environmental accidents, with most remarkable the *Amoco Cadiz* incident which had devastating effects to the marine environment. IMO and ILO unanimously agreed that there should be better co-ordination between regions in order to prevent reduce accidents promoted the implementation of conventions. After the meeting in Paris and the signing of the agreement, 14 countries were involved. Today, the Paris MoU is composed out of 27 countries: Belgium, Bulgaria, Canada, Croatia, Cyprus, Denmark, Estonia, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Latvia, Lithuania, Malta, the Netherlands, Norway, Poland, Portugal, Romania, the Russian Federation, Slovenia, Spain, Sweden and the United Kingdom (Parismou.org, 2018; Knudsen and Hassler, 2011).

The highest authority body in the Paris MoU is the Port State Control Committee (PSCC). The committee is responsible for the decision making and the execution authority for the organisation. Main priorities are matters relating to policy, finance and administrative decisions. It is composed by representatives from all the agreed states within the regions as well as the EU Commission. The Paris MoU retains good working co-operation with the USCG and the Tokyo MoU with whom they meet once per year, together with other MoU, IMO and ILO representatives. Each state has the responsibility to provide an effective system to their respective PSC in order to accurately identify risky vessels. All results from the inspections are collected and transferred to the database in Saint Malo, France, where they are recorded and safeguarded. This also includes deficiencies and detentions handed by the PSC. Each month, the Paris MoU publishes a list with all the detained vessels based on the results of the inspections. The published information includes the detained vessel's name, owner, classification society and place/date of the detention with reference also to the reason that led to its detention. All PSCO performing the inspections are trained under a specific program provided by the EU Commission (Xu, 2001).

##### 4.3.1.1 Targeting

Besides the effective targeting system by each state, there has been developed a set of rules that must be followed by all regional members. To begin with, at least 25% of all the foreign vessels entering a state's port yearly, must be inspected by the PSCO. The way that regional agreements are formed, it provides fair competition for all states in the agreement. In 2011 the Paris MoU introduced the New Inspection Regime (NIR), which allowed the creation of risk profiles for all incoming vessels. This way, it was made possible almost all foreign high risk vessels in the region can be inspected. All substandard vessels which are regarded as "High Risk Ships" (HRS) will have an

interval period of 6 months until the next inspection is performed. On the other hand, there are two more categories for vessels:

- i. The Low Risk Ships (LRS) that are rewarded with a period of 24 months.
- ii. The Standard Risk Ships (SRS), with an interval period of 12 months.

The creation of the risk profile is composed out of specific characteristics of the ship: age, type, flag state, recognized organisations (RO) and company performance.

Once a vessel, regardless of risk profile, is through with its interval period, then it the port state will categorise the specific vessel as a Priority 1 vessel (PI) and will have to inspect it. Vessels that could be inspected during an inspection periods as their interval is ending, are assigned to a Priority 2 category (PII). All HRS will have to be performed on extended inspections while standard risk have the possibility for more detailed inspections if there is valid ground to step in. The table below presents in detail how each profile is being validly created (Degré, 2008; Piniella and Rodriguez, 2012).

				Profile			
				High Risk Ship (HRS)		Standard Risk Ship (SRS)	Low Risk Ship (LRS)
Generic Parameters				Criteria	Weighting points	Criteria	Criteria
1	Type of ship		Chemical tankship Gas Carrier Oil tankship Bulk carrier Passenger ship	2	neither a high risk nor a low risk ship	All types	
2	Age of ship <sup>1</sup>		all types > 12 y	1		All ages	
3a	Flag	BGW-list <sup>2</sup>	Black - VHR, HR, M to HR	2		White	
			Black – MR	1			
3b		IMO-Audit <sup>3</sup>	-	-		Yes	
4a	Recognized Organization	Performance <sup>4</sup>	H	-		-	High
			M	-		-	-
			L	Low		-	-
			VL	Very Low		1	-
4b		Organizations recognized by one or more Paris MoU Member States	-	-		Yes	
5	Company	Performance <sup>5</sup>	H	-		-	High
			M	-		-	-
			L	Low		-	-
			VL	Very Low	2	-	
Historic Parameters							
6	Number of def. recorded in each insp. within previous 36 months	Deficiencies	Not eligible	-		≤ 5 (and at least one inspection carried out in previous 36 months)	
7	Number of Detention within previous 36 months	Detentions	≥ 2 detentions	1		No Detention	

Table 1: Risk profile for ships (Kustcodex.be, 2018)

As it can be seen from the table, flags are an important aspect in setting a profile. The Paris MoU has been using for the past years a flag differentiation system in order to recognize how responsibly flag states implement the safety conventions to their registered vessels. It has generated a Black/Grey/White (BGW) list of flags based on the results from the PSCO inspections. The list is made based upon the results of the past three years and every year a renewed list is published by the committee. As Black flagged ships are marked all risky ships including the HRS, while grey flag indicates low performance standards. A similar list with the highest performing ROs is also being published, again based on the results from the PSC inspections (gCaptain, 2018).

#### *4.3.1.2 Ballast Water Monitoring*

With the enforcement of the IMO convention regarding BWM, compliance of the convention should be monitored by the PSCO. Prior to the ratification, ballast water was not independently inspected the PSC. All vessels should obtain all the requirements as mentioned in chapter 3, in order to prevent getting deficiencies from the PSC. Unless those deficiencies are dealt successfully by the vessel's crew, the vessel is in danger of getting detained.

Given the vessels risk profile that has been established by the Paris MoU, the data base of the memoranda can provide all the detained vessels since the ratification of the convention until today. The reason that the ship was detained is also mentioned, as well as their name, owner, flag and place of the detention. Moreover, all ballast water related deficiencies are also recorded, with classification according to the nature of the deficiency (missing of BWRB or BWMP) and the characteristics of a vessel (age, type and flag). The available data begins from 09/2017 until today and can be interpreted either monthly or yearly. This will also be the data required for completing this research and finding the relation between the nature of the deficiencies and a vessel's main characteristics.

#### 4.3.2 United States Coast Guard (USCG)

The authority responsible for the marine protection at the United States is the US coast guard. The USA has established its own regulations regarding the various aspects of marine environment and is not a member of IMO as well as any of the regional agreements. The USCG was established in 1915, and is primarily a military service in the armed forces. It is also responsible for safe navigation within territorial waters and pollution prevention. The main suspicious targets for inspection were tankers and passenger ships. Due to the bad performance of US vessels, as of May 1<sup>st</sup> 1994 the USCG began to get involved with PSC activity. The purpose of its creation, is for the US government to ensure that all international conventions are strictly followed, with an annual report published every year with the results from the inspections. The performance of US and global owners, charterers, ROs and flag states.

The USCG prior to the jurisdiction power from PSC, would only interfere to the regulations of international conventions for suspicious non-US vessels. All legal provisions applying to vessels are certified within US Code. Under section 3303 of the Code, it is stated that the USCG is committed in the implementation of international conventions. Even though the standards are based on those conventions, there are still some alternations due to some national requirements. The highest in ranking

power in the coast guard is the Commandant. The duties given to officers are referred to as “captain of the port”. His has full responsibilities for the organisation and has jurisdiction to perform any act that ensures compliance with the conventions is met (Kulchytskyy, 2012).

The publications of directives (MSMs) has contributed in the foundation of the PSC in the US. It provides all legal requirements of PSC, provisions for the training of PSCO and grounds for boarding conditions. Inspections to test compliance usually requires the proof of a valid certificate issued by an established authority. All foreign vessels US ports are subject to inspection for compliance with the conventions, as mentioned in the Code. Those conventions include the majority of IMO and ILO conventions such as: LOADLINE, SOLAS, MARPOL, TONNAGE, STCW 78/95 and ILO 147. The USCG has also being active against the potential threat and pollution of ballast water since 2012 (Bang, 2008).

#### *4.3.2.1 Targeting*

Similarly to the Paris MoU technique, the USCG applies an Environmental Protection Compliance Targeting Matrix for determining risky vessels. The Matrix contains three tools used to identify the scale of the risk. In order for Matrix to perform, all vessels should submit a Notice of Arrival (NOA) at least 96 hours prior to its arrival. Combined with the NOA, incoming vessels are also obliged to provide basic information of the vessel, crew declaration or visas status and nationality as well as proof of compliance with the content of the ISM and ISPS Code.

The first tool is the High Interest Vessel Matrix. It is used for all vessels entering a US port. It determines the level of danger for vessels prior to entering the port. If through the first matrix there are signs of increased danger for a vessel, then the remaining two matrixes will have to be applied as well. All such vessels will also have clear ground for boarding by PSCO before it can enter the port and should be the first ones to get inspected. Depending on the positions of the vessel and the deficiencies identified by the officers, a ship may even be restricted to enter a port. The second tool, known as ISPS/MTSA Security Compliance Matrix, is applied for further determining the risk levels of High Interest Vessels. Its targeting concept is to identify the history ship management authority, flags, ROs and previous ports of the corresponding vessel to figure the compliance levels of the international convention and particularly the SOLAS convention (Kulchytskyy, 2012).

The final tool is the Environmental Protection Compliance Targeting Matrix and is composed out of 5 parameters that all contribute in each vessels personal targeting score. Each parameter worth's as value points, contributing to a final score for each incoming vessel. Those parameters are:

- i. Ship Management
- ii. Flag state
- iii. ROs
- iv. Vessel History
- v. Ship Particulars

Those with the score of 17 and higher, will be considered as Priority I (PI) vessels for inspections, as imposed to the Paris MoU system. This indicates that the classification

society of the vessel has been awarded with detentions over the past year and has a detention rate 4 times higher than the average. Priority II (PII) vessels, are medium targeted vessels with score between 7 and 16. PII vessels are highly noted for the lack of PSC inspection over the last 12 months. A vessels history is also crucial for resulting in decisions as past marine violations or previous port visits. Such vessels are permitted to enter the port, however they are likely to be inspected prior to their port operations. Scores below 7 show that a vessel opposes low risk and could only be inspected randomly for routine purposes (USCG Annual Report, 2017).



Table 2: High Interest Vessel Matrix (SAFETY4SEA, 2018)

#### 4.3.2.2 Ballast Water Monitoring

The US has been increasingly aware of the invasive species problem that is caused through ballast water. As mentioned in the literature, this is also proven by the introduction of foreign species being found in US territorial waters. As of January 2012, the US entered into force the 33 Code Federal Regulations 151 implementing the adaption of a ballast water program. Responsible authority that has all the jurisdiction regarding ballast water monitoring in the US, is the coast guard. The program is called The Final Rule and provides the standards for the allowable concentration of living organisms discharged into US waters through ballast. The majority of the regulations align with the requirements of the 2004 IMO BWMC,

however the main difference is that the USCG set limits on the living organisms identified inside the ballast water whereas IMO limits the viable organisms.

The final rule was created for the prevention of allowing NIS enter the coasts of USA. The alignment with the IMO convention will arise similar requirements by the USCG. All vessels must show proof of related certificates such as the BWMP and BWRB. Most importantly though, it requires the installation of BWMS that has already been approved by the USCG. The lack of such documentation from vessels and the lack of familiarisation in BW procedures by the crew will result in deficiencies by the USCG until the matter is solved. According to the USCG annual report, below is shown the most awarded deficiencies by the CG for 2017.

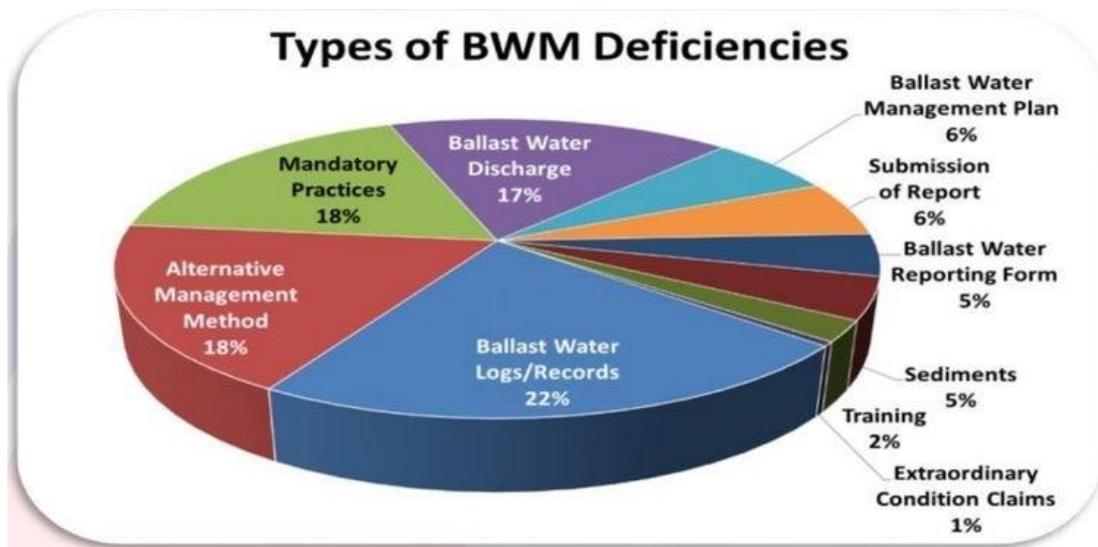


Chart 1: USCG share of Ballast Water Deficiencies for 2017 (Gunton, 2018)

The total number of deficiencies in 2017 were 216 in total, resulting in an increase of 99.1% compared to 2016. The final rule has also other options to allow vessels comply. All foreign BWMS that are not approved by the USCG, are considered Alternate Management Systems (AMS) and they have to be inspected by the coast guard in order to be accepted. Yet, as it can be seen from the chart, 18% of the total deficiencies were caused with the using of an AMS. Alternatively, USCG may grant an extension for a vessel to get complied until then (Gunton, 2018).

#### 4.3.3 Tokyo MoU

The third MoU to get established has been the Tokyo MoU in 1993. It represents the Asia-Pacific region and has currently signed 20 member states: Australia, Canada, Chile, China, Fiji, Hong Kong (China), Indonesia, Japan, Republic of Korea, Malaysia, the Marshall Islands, New Zealand, Papua New Guinea, Peru, the Philippines, the Russian Federation, Singapore, Thailand, Vanuatu and Viet Nam; Some of the members like Russia and Australia are also included in other MoUs, the Black Sea

and Indian respectively. Responsible for all the actions taken within the MoU is the PSC committee. It is established to overlook the effectiveness of the MoU and ensure correct decision-making. It is served by members of all contracting states and a permanent secretariat (Tokyo MoU Secretariat - TMS) (Tokyo-mou.org, 2018).

All international conventions that apply to the Paris MoU, do so at the Tokyo MoU as well. Their compliance is the primary target in case of an inspection. Tokyo MoU has strong relationships with the Paris MoU as well as IMO and ILO. They are invited, together with representatives with other MoU in the meetings of the Memoranda. Training programmes have been created by the PSC for PSCO to gain the necessary qualifications. All reports from the inspections are exchanged across the MoU s that all can have access to the information. For this reason, the Asia-Pacific Computerised Information System (APCIS) was established as a database for all recorded reports (Xu, 2001).

#### *4.3.3.1 Targeting*

The Tokyo MoU has established its own targeting tool for identifying risky vessels. Normally, the MoUs have a standard scheme for seeking risky vessels but similar to the Paris MoU, the Tokyo Memoranda has developed a system inspired by the one applies in Paris. The main difference remains that Paris MoU's unique system can determine the priority listed vessels. This allows the authority to immediately inspect the vessel prior to its port entrance or before its port operations. Especially for PI vessels, the Paris is committed to inspect all high risk vessels. Opposing, the Tokyo MoU system has an 80% of risky vessels entering regional ports. Those two MoUs have the highest percentage in vessel inspection are considered to be leading ones (Kara, 2016; Kulchytsky, 2012).

The Tokyo MoU, like all other MoU, tries to identify dangerous vessels entering the region. The ratification of all international conventions already mentioned makes it mandatory for all vessels to meet their requirements. The PSC primarily targets bulk carriers, passenger and roll on/roll off vessels for inspection as well as those that carry dangerous cargo – (chemical) tankers. History of a vessel is also crucial in the final decision upon its vessel. The lack of an inspection over the past 6 months or the award of deficiencies and detentions from previous ports, definitely contribute upon high risk vessel selection. At last, Tokyo MoU calculates the risk factor of flags. As Paris MoU, it has generated BGW flag list to identify the level of risk for all flagged incoming vessels. This is also a way to deal with the increasing problem of owners registering their vessels to FOC that neglect the effect of environmental protection conventions (Fan et al., 2014; Emecen Kara and Oksas, 2016).

## Chapter 5. Methodology

### 5.1 Research Model

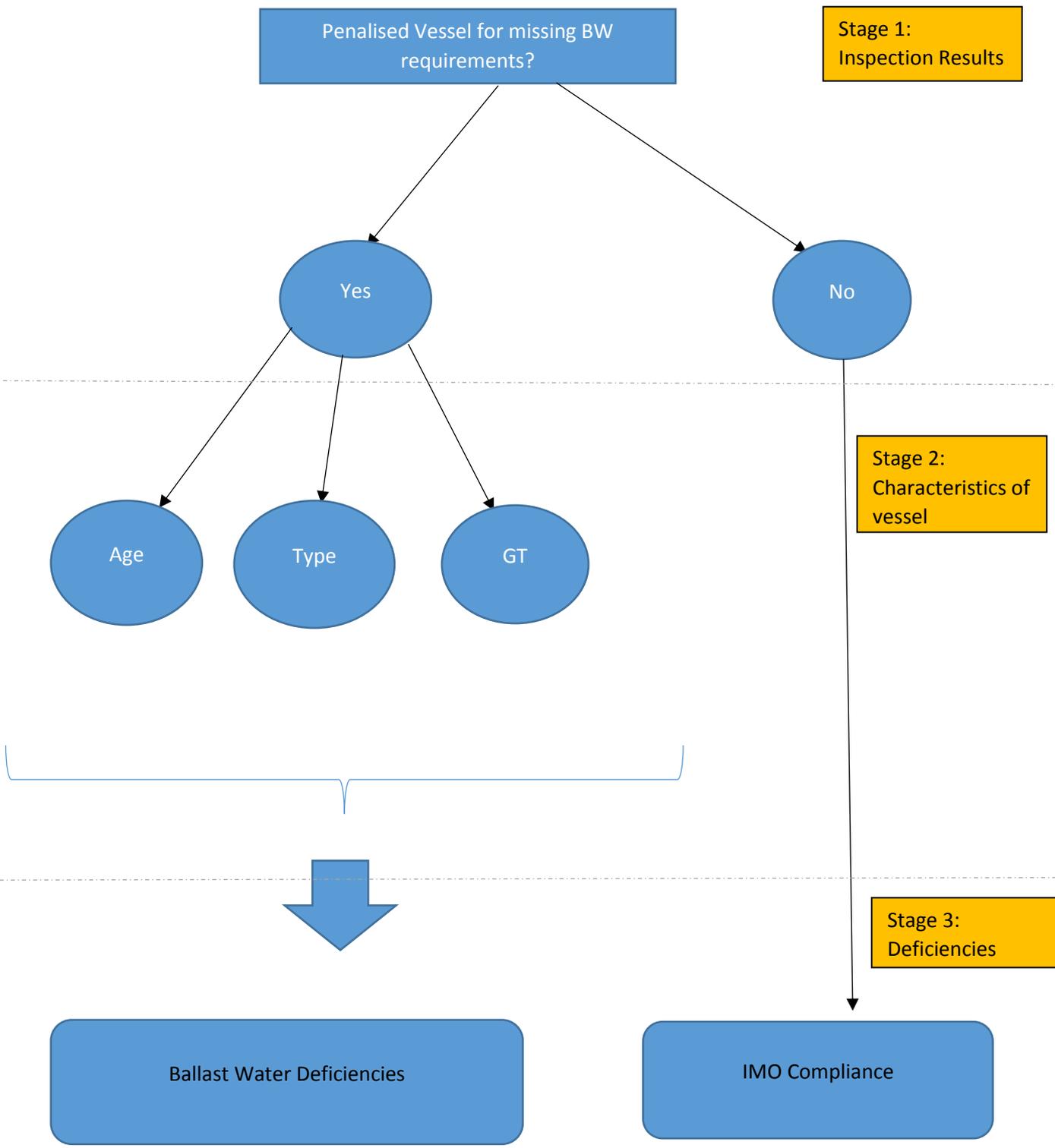
Having already investigated the structure of the port state authorities as well as their inspection procedure, it is now time to speculate how the deficiencies applied to vessels relate to their combination of main characteristics. As already identified, there are some criteria upon vessel selection by the PSC. Those include:

- Vessel type
- Vessel age
- Flag state
- RO
- Gross Tonnage (GT)

On the other hand, port state has the authority to apply a deficiency to vessels not in compliance with the ballast water standards as mentioned in the IMO convention. The most common deficiencies applied are regarding the following:

- Ballast Water Record Book
- Ballast Water Exchange
- Ballast Water Management Plan
- Crew training / Familiarisation
- Discharge Violation in Port
- Ballast Water Management Systems

For this research, the interrelation of those variables should provide us with patterns between the nature of deficiencies and the main characteristics of a vessel. Main responsibility is that vessels must be selected for inspection, unless they are considered as Low Risk Ships (LRS), and their inspection is not mandatory but only random. The results will show how PSC prioritises its inspections and what vessels are most commonly penalised with specific deficiencies. It will allow us to find a possible sequence of characteristics for vessels that have been selected for inspection and are subject to ballast water deficiencies. It would be interesting to figure what combination of vessel characteristics have been mostly penalised after the ratification of the convention nearly one year ago. The limited data available only allows us to make a first assessment on the distribution of deficiencies awarded. Due to the familiarisation phase in the adoption of the D-2 regulation of the IMO, BWMS will be excluded as it is a new requirement for owners contracted to the IMO. Given the installation period that owners are allowed to familiarise with those systems, it has been decided not to be included as a research variable.



## **5.2 Research Design**

There are two main paths upon deciding the design of the research. A research could either follow a more qualitative path, which will be based on gathering theoretical information of a topic and is a way to gain better understanding of a topic. It allows to have a better insight behind trends of the variables. Many times, qualitative based designs lead to various hypothesis due to a better understanding of a respective topic. Hypothesis and assumptions invite the involvement of quantitative based research. Quantitative data generates numerical data, which are later interpreted by different techniques. A quantitative research aims to draw conclusions from the data interpretation and results will have to be examined whether they validate to the initial hypothesis or not.

First sub-question, shall indicate basically the requirements of the D-2 regulation which will become in force. Qualitatively, this can be completed through the IMO convention which states the requirements needed. Following, the third sub-question shall outline the responsibilities of a PSCO and the criteria of vessel selection for inspection. Again, a qualitative approach will be used with respect to the main challenges that officers are facing in inspections. The result of PSC inspections are submitted to the regional MoUs that a country is registered in. Particularly this study will be subject to the European and American MoUs, whose differences will be outlined and the results from their data inspection platforms, regarding the deficiencies, will be analysed. For this question, a quantitative approach will be required in order to identify the relation between awarded BW deficiencies and the particulars of the vessel that has been awarded to. The sample size will be made out of vessels that have been identified as risky, through the process of vessel via the vessel risk profile. Given the available data from the MoUs, a decision tree model will be used to identify the main characteristics of vessels violating the PSC requirements which results in deficiencies.

In order to be specific, data will be derived from the Paris MoU given that there is no available data for the USCG reports. The path in the probability tree can hopefully provide us with a pattern for deficiency penalties given, and thus help owners to minimize possible detentions and deficiencies related to ballast water management.

## **5.3 Research Method**

Even though the majority of the collected data will be qualitative, it will still contain some quantitative research. More specifically, the research method will allow us to interpret the data through various methods. A common technique, and also subject to this research, to analyse numerical data and find their relation is through the decision tree model. It is a chart that will allow us to perform statistical probability analysis on the collected data.

To be more specific, it is a model that provides solutions and can be used for forecasting specific events as well. The framework of the decision tree can present all the available options and outcomes based on a sequence of events. Each event has branches which are labelled and assigned with a probability. Depending on the data,

each branch is divided into chanced nodes that offer more outcomes (Khan Academy, 2018). As it can be seen in figure 1, D represents an event at level 1 and we would like to investigate what where the causes of its creation. As mentioned already, the probability tree will be used to calculate the characteristics of vessels that are awarded with deficiencies. The different deficiencies will represent the event at this level. Hypothesis are taken, creating breaches between nodes creating different possible combinations of vessel characteristics. The probability (P) of  $H_i$  for causing deficiency D is  $\theta_i$ . This mathematically is shown as:

$$P(H_i | D) = \theta_i$$

The sum of all probabilities at each event should be equal to 1, as the model is based on the law of probability. Through the branches, there are various paths created inside the chart, each one leading to exclusive outcomes. This outcome will be in the form of a probability (Brito, Smeed and Griffiths, 2014; Scarrott, 2011).

Through the decision tree model, all paths of ballast water deficiencies are in relation to the aforementioned vessel characteristics, resulting in different patterns and combinations. The final outcome of a path will be a probability that has been calculated under the consideration of previous events' results. There are three types of decision tree diagrams. The division in nodes can be made in three categories: chance, decision and end. Chance nodes include probabilities at branches in decision making (0.6/0.4), while decision nodes have decisions. At end nodes, the path in a tree diagram does not extend further. As the data will be in terms of percentage, chance nodes will form the tree decision chart in this research (Lucidchart, 2018).

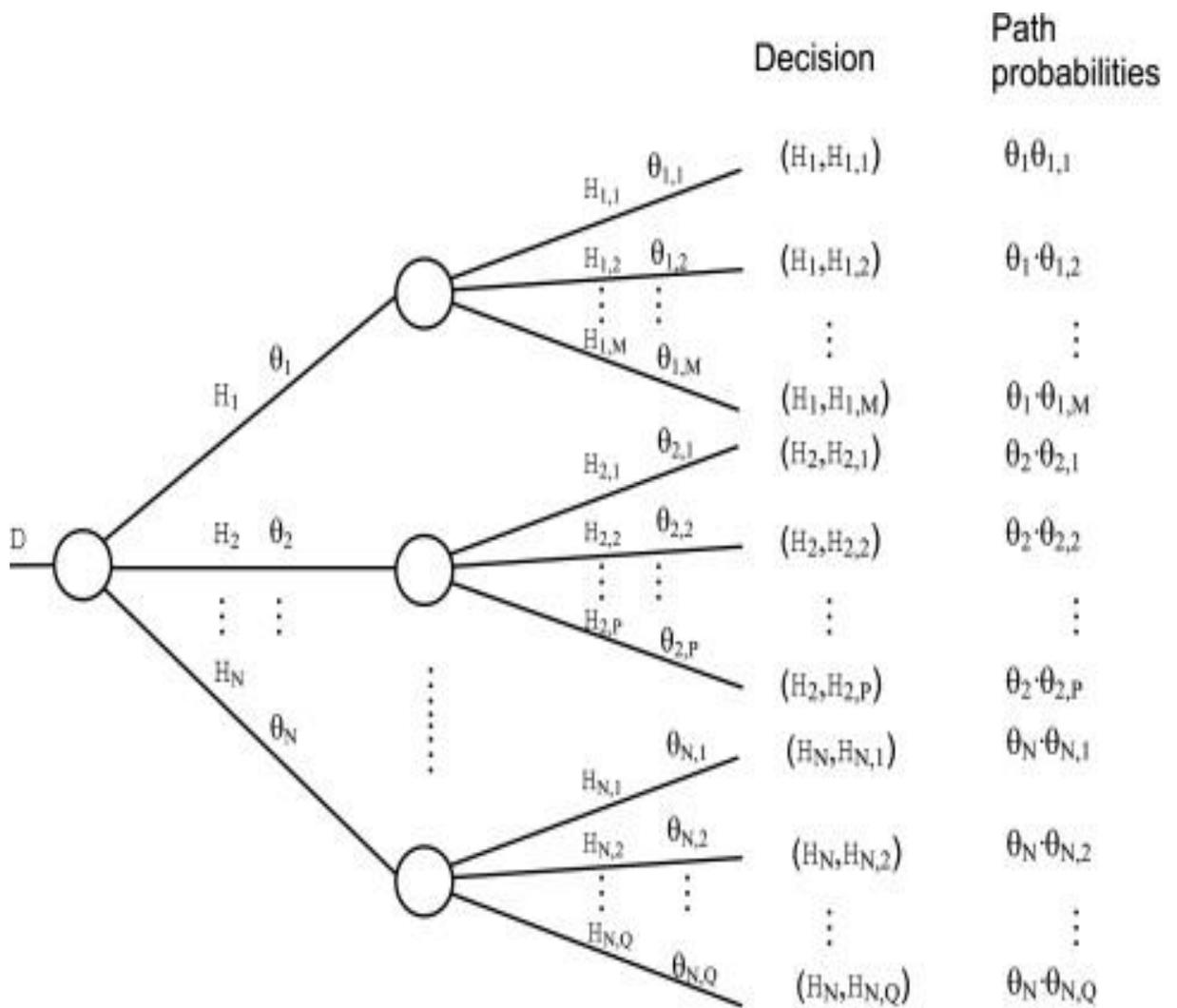


Figure 3: Generic probability tree for a combination of two events (Brito, Smeed and Griffiths, 2014)

The information collected regarding the analysis will be derived from secondary data. Data is divided in two categories: primary and secondary. Primary data constitutes of information gathered for the first time and for the scope of the research, such as interviews and surveys. On the other hand, secondary data constitutes of data already collected and published in the websites of organisations or presented in past researches. Data collected for this research will be secondary. All related conventions and regulations regarding ballast water and its monitoring by the PSC are publicly available information. Moreover, the data collected from the MoUs is also accessible via the websites of the selected memorandums. No primary data will be required for the completion of this research (Saunders, 2012).

## **5.4 Application & Data Collection**

### **5.4.1 Model Application**

In order to successfully use a probability tree model, the data must be based on incidents that have already happened, meaning that the data must be already occurred and recorded. Since the data already exists, we are going to use an Event Tree Analysis (ETA). It is known to be a very accurate tool in interpreting data and reaching conclusions or assumptions. It is easily applied and suitable to perform the research given the time restrictions. Depending on the number of events or variables and their nodes, it will determine the size and complexity of the final tree model. The probability tree diagram for this research will be composed out of three events:

- i. Type of Ballast Water Deficiencies
- ii. Vessel Age
- iii. Vessel Type
- iv. Gross Tonnage

It will be a four-event probability diagram, one for each of the above independent variables. The options of respective ROs and flags of each vessel will not be included due to the apparent results from the descriptive statistics. Each event will have 3-5 nodes, with branches connecting them together. For ballast water deficiencies, each node will represent a different deficiency. The nodes for the vessel type event will represent a different type vessel while age is categorised with a difference gap of 10 years. Similarly, GT will be classified in three divisions. All data collected will be subject to the total amount of ballast water deficiencies awarded. The value of the final probability is determined through a multiplication of all the branch probabilities included in the path, given there are independent. This can be simply be found by using the product rule. Taken the example in figure 1, the sequence of events  $H_2$ ,  $H_{2,2}$  will be:  $P(H_2, H_{2,2}, D) = P(H_2 | D) * P(H_{2,2} | H_2)$  (Brito, Smeed and Griffiths, 2014).

This way, we will be able to break down patterns that show the highest possibility of being awarded with different deficiencies. The various ballast water deficiencies will be the initial event, which will be analysed through the different types, ages and size of vessels punished. The more paths created, more are the sequences to be created as well. The sum of all the outcomes generated should be equal to 1 as well. All data collected for the sample are collected from the official website of the Paris MoU. The website provides an advanced search engine that allows you to identify the total number of deficiencies awarded at ports within the region. Moreover, with the introduction of the NIR has allowed to investigate in depth the results from the PSC inspections. Results are presented in the next sub-chapter.

### **5.4.2 Data Presentation**

Currently the Paris MoU has available all data collected from PSC inspections since June 30<sup>th</sup>, 2015. The total amount of inspections performed until the 30<sup>th</sup> June of 2018 is 53,571. Out of those inspections, in 27,555 cases the ship was awarded with at least one deficiency. The total number of inspections has reached 117,285 out of 2015 of them resulted in a detention. This gives a detention rate for the Paris MoU of 3.76% which is calculated by dividing the total detention awarded the total number of inspections performed (Shipping-kpi.org, 2018). Nevertheless, this research is still

based on the monitoring of ballast water deficiencies. Since its enforcement came last September, there are no previous records of ballast water deficiencies except from those available from the past 10 months (09/2017 - 06/2018).

When an inspection is made on a vessel, all of its main characteristics are now identified thanks to the NIR system. Its adoption has allowed access to all inspected ship's information including: IMO number, name, flag, type, age, classification society (RO), GT, ISM company number and type of inspection. Moreover all recorded deficiencies and detentions are also available. For the matter of this research, all data will be related to BW inspections and will be used as data for the tree probability model. During those months, a total of 14,310 inspections, resulting to 32,220 deficiencies and 508 detentions. The total inspections in regards of ballast water requirements were 319. The sample has a total number of deficiencies identified as 368 while the total detentions are 30. Out of the 368 deficiencies, 4 resulted in detention based on the PSCO jurisdiction.

Type of Deficiencies	No of Deficiencies	Detained	Distribution (%)
Ballast Water Record Book	155	0	42.1
Ballast Water Exchange	85	0	23.1
Ballast Water Management Plan	72	2	19.6
Crew Training	30	1	8.1
Others	26	1	7.1
<b>Total</b>	<b>368</b>	<b>4</b>	<b>100</b>

Table 3: Type of BW deficiencies and distribution (Parismou.org, 2018)

In the first table above, we can see the different types of ballast water deficiencies and how each one distributes to the total 368. The highest number of deficiencies awarded were related to the BWRB which is responsible for almost half of the total deficiencies (42.1%). A large portion of the sample vessels had also been penalised for not being compliant with the BWE and BWMP requirements having 23.1% and 19.6% respectively. Other notable incidents mainly included poor crew qualifications (8.1%), probably due to the lack of sufficient training and lack of familiarisation of the BW equipment. Discharge violation deficiencies match 3.3% of the total deficiencies given while the remaining 3.8% is subject to other related BW related deficiencies like the lack of BWMS.

Age of Vessel	No of Deficiencies	Distribution (%)
0-9	114	31
10-19	159	43.2
20+	95	25.8
<b>Total</b>	<b>368</b>	<b>100</b>

Table 4: Age classification of deficiencies and distribution (Parismou.org, 2018)

The classification in age is partially motivated by the dry docking schedule of vessels. The importance of dry docks is significant, as poorly completed docking could result in problems for the vessel during its activities that may as well contribute to the award of a deficiency. All vessels require to perform at least two dry dock inspections over the course of 5 years. These inspections become mandatory for vessels of 15 years old and older. For younger vessels, either new-built or under the age of 10, there exists the option to apply for an extended Dry-Docking scheme that will increase the interval of the inspections by 2.5 years. The scheme is available for young vessels and of certain type. This way is possible that new-built vessels could reach the age of 15 with only 2 dry docks performed (Kantharia, 2017). Most deficiencies are found at vessels of age between 10 and 19 years old, accounting for 43.2% of the total deficiencies. Even though newly-build ships have a small contribution to the total share (10.3%), vessels slightly older and aged between 5 and 9 years of age have reported two times the amount of deficiencies (20.7%) compared to the younger vessels. Totally, 31% of the deficiencies is caused by younger vessels. Someone would have expected that older vessels will have more deficiencies awarded, however in this sample vessels of 20 and over distribute 25.8% of the total deficiencies, for the majority of those are vessels aged over 25, while the lowest number of deficiencies has been provided by vessels between 20 and 24 years old with 9.8%.

The table below presents the division of deficiencies in terms of vessel type. The selection has been based on the vessel types that were mostly penalised by the PSC for failing to comply with the requirements of the IMO convention. General Cargo and Bulk Carriers contribute to more than half of the total deficiencies awarded. General Cargo vessels represent 30.5% of the total deficiencies awarded, topping the relevant list. Second come Bulk Carriers accounting for 20.7%. Regarding the tankers, 13.5% of the deficiencies has been given to chemical tankers and 9.5% to oil tankers. They have been considered as one type, contributing together 22.8%. Containers are also responsible for 9.5% of the final count, while other types including gas tankers and Ro-Ro carriers, representing 16.8% of the whole.

Type of Vessel	No of Deficiencies	Distribution (%)
Bulk Carrier	76	20.7
General Cargo	111	30.2
Tankers	84	22.8
Others	97	26.3
<b>Total</b>	368	100

Table 5: Vessel classification of deficiencies and distribution (Parismou.org, 2018)

Recognised Organisation	No of Deficiencies	Distribution (%)
American Bureau of Shipping	31	8.4
Lloyds Register	60	16.3
DNV GL AS	80	21.7
Bureau Veritas	55	14.9
Korean Register of Shipping	13	3.5
RINA Services S.p.A.	31	8.4
Nippon Kaiji Kyokai	39	10.6
Russian Maritime Register of Shipping	13	3.5
Phoenix Register of Shipping	3	0.8
Others	43	11.7
<b>Total</b>	368	100

Table 6: ROs of penalised vessels and distribution (Parismou.org, 2018)

Next variable is that of the Recognised Organisations in the table above. Paris MoU has categorised the ROs in terms of performance, from the highest to the lowest performers. The 9 ROs presented are all considered as high performers according to the most recent list published by Paris MoU. DNV GL AS has been involved in the most deficiencies with a total of 21.7%, followed by Lloyds Register with 16.3%. Notable contributors are also the Bureau Veritas (BV) and Nippon Kaiji Kyokai with

14.9% for BV and 10.6% for the latter. The list with the high performers concludes with ABS, RINA and the Korean Register of Shipping being involved with slightly above 20% of the total deficiencies. Others are composed by ROs of lower or medium performance, as categorised by the Paris MoU, contributing 11.7%. As it can be seen from the sample, the majority of vessels being inspected are registered to a high performance classification society.

Age of Vessel	No of Deficiencies	Distribution (%)
Antigua & Barbuda	27	7.35
Liberia	27	7.3
Malta	32	8.7
Marshall Islands	39	10.6
Panama	40	10.9
Singapore	14	3.8
Cyprus	18	4.9
Others	171	46.8
<b>Total</b>	368	100

Table 7: Flag register of penalised vessels and distribution (Parismou.org, 2018)

The final two variables included in this research are the flag state of each inspected vessel and its total size measured in Gross Tonnage. The two leading flag registries that have been accounted for the most ballast water related deficiencies, are Panama (10.9%) and Marshall Islands (10.6%). Following flags that are subject to inspections are Malta with 8.7% of the total share and Liberia with Antigua & Barbuda, contributing each 7.3%. Double figured deficiency flags also include Singapore and Cyprus with respective distribution of 3.8 % and 4.9%. Others country include those with less than 10 recorded deficiencies. All of the most penalised flags are considered as White flag vessels known for being less risky towards the environment. In fact, 86.4% of the related deficiencies are related to white flag vessels, whereas Black and Grey flagged nations contribute the remaining 13.6%. In table 9, the division by GT is made with distribution being alike by all vessel sizes. The majority of inspected and penalised (40.7%) were 7500 GT or less. Just to remind in this point, that all vessels of 400 GT and above are obliged to follow the requirements of the IMO convention and thus are subject to inspection by the PSC. Larger scale vessels of over 40,000 GT contributed 29.1%, almost the same to more middle sized vessels (30.2%).

<b>Flag Category</b>	<b>No of Deficiencies</b>	<b>Distribution (%)</b>
White Flags	318	86.4
Grey Flags	19	5.2
Black Flags	31	8.4
<b>Total</b>	<b>368</b>	<b>100</b>

Table 8: Flag classification of penalised vessels and distribution (Parismou.org, 2018)

<b>Gross Tonnage</b>	<b>No of Deficiencies</b>	<b>Distribution (%)</b>
400 – 7500	153	40.7
7501 – 40000	111	30.2
40000 +	104	29.1
<b>Total</b>	<b>368</b>	<b>100</b>

Table 9: Cross Tonnage Scale of penalised vessels and distribution (Parismou.org, 2018)

## Chapter 6. Analysis and Results

### 6.1 Sample Collected

In the following chapter, results derived from the probability tree model will be presented. The data found above, will be used as inputs for the model. As mentioned in chapter 5, the model will be formed out of four events. Based on the results, it has been decided that descriptive statistics regarding the ROs and flag states will not be included in the model. There are two principal reasons for this. First of all, as an evident assumption, based on the collected data. The classification of both flags and ROs has been made under specific characteristics. High performance recognised organisations have been awarded 88.3% of the total deficiencies with the remaining provided by medium and low performance ones. Similarly to the flag of vessels, the majority of deficiencies has been rewarded to white flagged vessels (86.4%). Moreover, the tree with the data already collected will be extended enough. With four events, two with three nodes, one with four and one with five. There will be a total of 180 branches ( $= 3^2 \cdot 4 \cdot 5$ ) connecting the nodes together.

The tree aims to investigate how the different vessel characteristics have an impact on BW related deficiencies. In the methodology, it was stated that an important aspect is to create hypothesis that will provide more branches. Main consideration before applying the probability tree model for this research, is that the results will also be valid for vessels inspected with ballast water deficiencies between the periods 09/2017 - 06/2018. The table below shows the total number of deficiencies awarded during that period, however we will focus only on the ballast water related ones. As shown in the model, the sample will be made from all vessels that have been awarded ballast water deficiencies. This equals to 1.15% of the total deficiencies awarded by the PSC of the regional agreement. If a vessel has not been awarded with a deficiency, it is provided that it is complied with the requirements of the IMO convention. The vessels that are subject to inspections are selected through the targeting system that Paris MoU has established, but this will be determined by the final results.

Vessels Inspected	Total Deficiencies	BW Related	Distribution of BWD (%)
12,836	32,220	368	1.15

Table 10: Ballast Water related deficiencies out of the total (Parismou.org, 2018)

## 6.2 Probability Trees

The deficiencies, depending on their nature, were divided in five categories. Thus, there will be 5 tree representations created, one for each deficiency. Originally, this would have been a united tree but due to space constraints it will be broken down. The tree was made through an online calculator, while the final customisation was made at Microsoft Excel. Given the main characteristics of vessels collected from the inspections results and the distribution of ballast water deficiencies, we will conclusively have the conditional probability for each deficiency to be awarded. Each of the following subchapters, will have a different type of deficiency as the initial event and thus a different distribution percentage. All of the different deficiencies, will be combined with the same vessel characteristics in order to find the likelihood of each deficiency to occur, given those characteristics. The sum of all the probabilities found from the all the oaths created should equal to 1, as in accordance to the law of probability. Each ballast water deficiency will be chosen as an initial event. In order to reduce the complexity of the results from the final tree, the most noticeable final probabilities will be presented. The colouring differentiation can make presentation of the results more prominent, as increased probabilities will be highlighted with red or shades of red depending on their value. This has been modified via Excel, in order to mark out the paths with the possibility of occurrence. Opposing, sequences with a lower probability to occur will be highlighted with greenish colours.

### 6.2.1 BWRB (42.1%)

TYPE	AGE (Y.O.)	SIZE (GT)	(P)	(%)
<b>General Cargo</b> <b>0.302</b>	<b>0-9</b> 0.31	<b>0-7500</b> 0,407	0,016042	1,60%
		<b>7501-40000</b> 0,302	0,011903	1,19%
		<b>40000+</b> 0,291	0,011469	1,15%
	<b>10-19</b> 0.432	<b>0-7500</b> 0,407	0,022355	2,24%
		<b>7501-40000</b> 0,302	0,016587	1,66%
		<b>40000+</b> 0,291	0,015983	1,60%
	<b>20+</b> 0.258	<b>0-7500</b> 0,407	0,013351	1,34%
		<b>7501-40000</b> 0,302	0,009906	0,99%
		<b>40000+</b> 0,291	0,009546	0,95%

Figure 5: Probability of different outcomes for General Cargo vessels (part)

In the probability tree of the Ballast Water Record Book deficiencies, it was found that the sequence with the highest probability (2.24%) for occurring are general cargo (T2), vessels between 10-19 years of age (A2) and maximum of 7500 GT (S1). Given that the variables are independent, the sequence leading to that value will be the following:

$$\begin{aligned}
 P(\text{BWRB} \cap \text{T2} \cap \text{A2} \cap \text{S1}) &= P(\text{BWRB}) * P(\text{T2}) * P(\text{A2}) * P(\text{S1}) \\
 &= 0.421 * 0.302 * 0.432 * 0.407 \\
 &= 0.022355 \text{ or } 2.24\%
 \end{aligned}$$

TYPE	AGE (Y.O.)	SIZE (GT)	(P)	(%)
<b>Bulk Carriers</b> 0.207	0-9 0.31	0-7500 0,407	0,010995	1,10%
		7501-40000 0,302	0,008159	0,82%
		40000+ 0,291	0,007862	0,79%
	10-19 0.432	0-7500 0,407	0,015323	1,53%
		7501-40000 0,302	0,01137	1,14%
		40000+ 0,291	0,010955	1,10%
	20+ 0.258	0-7500 0,407	0,009151	0,92%
		7501-40000 0,302	0,00679	0,68%
		40000+ 0,291	0,006543	0,65%

Figure 6: Probability of different outcomes for Bulk Carriers vessels (part)

Based from the results arisen from the probability tree, the sequence that shows the lowest probability to occur for a BWRB deficiency is of general cargo vessels (T1), with age higher than 20 years (A3) and size over 40,000 GT (S3). The value is 0.65% which mathematically can be computed as follows:

$$\begin{aligned}
P(\text{BWRB} \cap \text{T1} \cap \text{A3} \cap \text{S3}) &= P(\text{BWRB}) * P(\text{T1}) * P(\text{A3}) * P(\text{S3}) \\
&= 0.421 * 0.207 * 0.258 * 0.291 \\
&= \mathbf{0.006543 \text{ or } 0.65\%}
\end{aligned}$$

The difference between the two extreme values is noteworthy given the limited sample we have. Going back to the targeting system of Paris MoU, Bulk carriers are considered amongst others one of the riskiest types of vessels, so it is surprising that BWRB related deficiencies are not highly associated to bulk carriers. Such risky vessel types are more intensively monitored by the PSC, being awarded also with more weighting points in a ships risk profile. On the other hand, the highest possibility that BWRB deficiencies will be awarded include general cargo ships of high age and size. General Cargo is not considered a type of risky ship, however ships of 12 years old and older are more subject to inspection by the port authorities of Paris MoU.

### 6.2.2 BWE (23.1%)

TYPE	AGE (Y.O.)	SIZE (GT)	(P)	(%)
General Cargo 0.302	0-9 0.31	0-7500 0,407	0,008802	0,88%
		7501-40000 0,302	0,006531	0,65%
		40000+ 0,291	0,006293	0,63%
	10-19 0.432	0-7500 0,407	0,012266	1,23%
		7501-40000 0,302	0,009101	0,91%
		40000+ 0,291	0,00877	0,88%
	20+ 0.258	0-7500 0,407	0,007325	0,73%
		7501-40000 0,302	0,005436	0,54%
		40000+ 0,291	0,005238	0,52%

Figure 7: Probability of different outcomes for General Cargo vessels (part)

Similarly, the same sequence of characteristics is possible to occur for deficiencies related to the ballast water exchange. It is the second most identified deficiency in the records of Paris 'MoU, only second to the BWRB. Middle aged general cargo vessels of size less than 7500 GT show the highest probability out of the other sequences.

$$\begin{aligned}
 P(BWE \cap T2 \cap A2 \cap S1) &= P(BWE) * P(T2) * P(A2) * P(S1) \\
 &= 0.231 * 0.302 * 0.432 * 0.407 \\
 &= 0.012266 \text{ or } 1.23\%
 \end{aligned}$$

Considering the requirements of the targeting scheme of Paris MoU, the results from inspections regarding BWE deficiencies do not fully match those requirements. Multipurpose vessels have shown an increasing amount of deficiencies despite not being considered risky vessels for the countries of the regional agreement.

TYPE	AGE (Y.O.)	SIZE (GT)	(P)	(%)
<b>Bulk Carriers</b> 0.207	<b>0-9</b> 0.31	<b>0-7500</b> 0.407	0.006033	0.60%
		<b>7501-40000</b> 0.302	0.004477	0.45%
		<b>40000+</b> 0.291	0.004314	0.43%
	<b>10-19</b> 0.432	<b>0-7500</b> 0.407	0.008407	0.84%
		<b>7501-40000</b> 0.302	0.006238	0.62%
		<b>40000+</b> 0.291	0.006011	0.60%
	<b>20+</b> 0.258	<b>0-7500</b> 0.407	0.005021	0.50%
		<b>7501-40000</b> 0.302	0.003726	0.37%
		<b>40000+</b> 0.291	0.00359	0.36%

Figure 8: Probability of different outcomes for Bulk Carriers vessels (part)

Again, the smallest likelihood of sequences to happen involve bulk carriers. Particularly, the sequence that provides the lowest probability is that of vessels over 20 years old and gross tonnage of over 40000 GT. The difference within smaller scale vessels is almost minimal, even though we cannot tell the same for even smaller ships. The probability formula will once again be used for determining the final probabilities of deficiencies related to BWE:

$$\begin{aligned}
 P(BWE \cap T1 \cap A3 \cap S3) &= P(BWE) * P(T1) * P(A3) * P(S3) \\
 &= 0.231 * 0.207 * 0.258 * 0.291 \\
 &= 0.00359 \text{ or } 0.36\%
 \end{aligned}$$

This is sensible up to a certain point as well. As already mentioned, older vessels are most exposed to dry dock arrangements, with mandatory inspections every 2.5 years. Successful and well-arranged dry docks could only benefit the vessel by improving its performance and not showing any signs of operational problems. Those may as well be the reasons for a potential deficiency at an inspection.

### 6.2.3 BWMP (19.6%)

TYPE	AGE (Y.O.)	SIZE (GT)	(P)	(%)
<b>Others</b> <b>0.263</b>	<b>0-9</b>  0.31	<b>0-7500</b> 0.407	0.006504	0.65%
		<b>7501-40000</b> 0.302	0.004826	0.48%
		<b>40000+</b> 0.291	0.00465	0.47%
	<b>10-19</b>  0.432	<b>0-7500</b> 0.407	0.009063	0.91%
		<b>7501-40000</b> 0.302	0.006725	0.67%
		<b>40000+</b> 0.291	0.00648	0.65%
	<b>20+</b>  0.258	<b>0-7500</b> 0.407	0.005413	0.54%
		<b>7501-40000</b> 0.302	0.004016	0.40%
		<b>40000+</b> 0.291	0.00387	0.39%

Figure 9: Probability of different outcomes for other types of vessels (part)

The third probability tree will examine the possible paths that could result in a deficiency related to the BWMP inadequacy. Even though general cargo still have the highest possibility to be liable to deficiencies regarding the management plan, in figure 9 we can see that “others” type (T4) of vessels 10-19 years of age (A2) and small in size (S1) show the highest sequences for a deficiency penalty. Mathematically this is proven as follows:

$$\begin{aligned} P(\text{BWMP} \cap \text{T4} \cap \text{A2} \cap \text{S1}) &= P(\text{BWMP}) * P(\text{T4}) * P(\text{A2}) * P(\text{S1}) \\ &= 0.196 * 0.263 * 0.432 * 0.407 \\ &= 0.009063 \text{ or } 0.91\% \end{aligned}$$

In the “others” category are included both risky and safer type of ships according to the targeting system of the Paris MoU. Amongst them container, Ro-Ro as well as specialised vessels like ones for refrigerated cargo. Yet, it also refers to more risky ones like gas carriers and passenger vessels. This also applies to all sizes of the middle aged other vessels having statistically a bigger probability to occur.

Another type of apparently risky vessels include all types of tankers (T3), both oil and gas. Accidents involving tankers have also been one of the reasons that the development of PSC was established. Accidents like the *Amoco Cadiz* have been used as examples for motives of the creation of PSC. Regarding the distribution of BWMP deficiencies, tankers have showed the lowest probability of being awarded a BWMP related deficiency for vessels of both younger (A1) and older age (A3) seem to have a smaller chance of being awarded with deficiencies regardless their size. Only exemption constitutes vessels following the sequence below:

$$\begin{aligned} P(\text{BWMP} \cap \text{T3} \cap \text{A1} \cap \text{S1}) &= P(\text{BWMP}) * P(\text{T2}) * P(\text{A1}) * P(\text{S1}) \\ &= 0.196 * 0.228 * 0.432 * 0.407 \\ &= 0.007857 \text{ or } 0.79\% \end{aligned}$$

Once more, small size vessels (S1) gain the higher possibility of being penalised. However as it can be seen from figure 10, middle aged vessels still are responsible for the highest distribution of deficiencies for the requirements of the BWMP in tankers.

TYPE	AGE (Y.O.)	SIZE (GT)	(P)	(%)
Tankers 0.228	0-9 0.31	0-7500 0.407	0.005638	0.56%
		7501-40000 0.302	0.004184	0.42%
		40000+ 0.291	0.004031	0.40%
	10-19 0.432	0-7500 0.407	0.007857	0.79%
		7501-40000 0.302	0.00583	0.58%
		40000+ 0.291	0.005618	0.56%
	20+ 0.258	0-7500 0.407	0.004693	0.47%
		7501-40000 0.302	0.003482	0.35%
		40000+ 0.291	0.003355	0.34%

Figure 10: Probability of different outcomes for tankers (part)

#### 6.2.4 Crew (8.1%)

A different type of deficiency concerns the crew's awareness of managing ballast water regardless the type and have the appropriate qualification to perform the procedures related to ballast water. It concerns vessels in which officers assess that the crew is not adequately qualified with the ballast water activities on board the vessel or is not in position to perform any related drill requested by the PSC officer. The results from the tree model provided that general cargo vessels on their second decade of their life continue to show the highest probability of being awarded with deficiencies. It follows the same sequence as other deficiencies awarded to vessels with the same characteristics (age, type and size):

$$\begin{aligned}
 P(\text{Crew} \cap \text{T2} \cap \text{A2} \cap \text{S1}) &= P(\text{Crew}) * P(\text{T2}) * P(\text{A2}) * P(\text{S1}) \\
 &= 0.081 * 0.302 * 0.432 * 0.407 \\
 &= 0.004301 \text{ or } 0.43\%
 \end{aligned}$$

TYPE	AGE (Y.O.)	SIZE (GT)	(P)	(%)
General Cargo 0.302	0-9 0.31	0-7500 0.407	0.003086	0.31%
		7501-40000 0.302	0.00229	0.23%
		40000+ 0.291	0.002207	0.22%
	10-19 0.432	0-7500 0.407	0.004301	0.43%
		7501-40000 0.302	0.003191	0.32%
		40000+ 0.291	0.003075	0.31%
	20+ 0.258	0-7500 0.407	0.002569	0.26%
		7501-40000 0.302	0.001906	0.19%
		40000+ 0.291	0.001837	0.18%

Figure 11: Probability of different outcomes for General Cargo vessels (part)

Figure 12 below, shows the lowest possible chances that deficiencies could be given to a vessel due to their crew performance regarding ballast water management. With the data collected during those months, there is very small probability that both old and relative young ships will face troubles with the PSC for their crew. To be more specific, the sequence that follows provide the combination of characteristics with the smallest probability to face such related deficiencies. This concerns bulk carriers of age over 20 years old of size above 7500 GT (S2 & S3):

$$\begin{aligned}
 P(\text{Crew} \cap T1 \cap A3 \cap S3) &= P(\text{Crew}) * P(T1) * P(A3) * P(S2) \\
 &= 0.081 * 0.207 * 0.258 * 0.302 \\
 &= 0.001306 \text{ or } 0.13\%
 \end{aligned}$$

TYPE	AGE (Y.O.)	SIZE (GT)	(P)	(%)
<b>Bulk Carriers</b> <b>0.207</b>	<b>0-9</b> 0.31	<b>0-7500</b> 0.407	0.002115	0.21%
		<b>7501-40000</b> 0.302	0.00157	0.16%
		<b>40000+</b> 0.291	0.001513	0.15%
	<b>10-19</b> 0.432	<b>0-7500</b> 0.407	0.002948	0.29%
		<b>7501-40000</b> 0.302	0.002187	0.22%
		<b>40000+</b> 0.291	0.002108	0.21%
	<b>20+</b> 0.258	<b>0-7500</b> 0.407	0.001761	0.18%
		<b>7501-40000</b> 0.302	0.001306	0.13%
		<b>40000+</b> 0.291	0.001259	0.13%

Figure 12: Probability of different outcomes for Bulk Carriers vessels (part)

### 6.2.5 Others (7.1%)

The final category formed was about the “Others” deficiencies. All the remaining type of deficiencies recorded by the port state were summed up in order to provide us with the remaining deficiencies out of the total 368. Almost half of them were caused due to discharge violations at ports while others also include BWMS related deficiencies. Yet, due to the small contribution to the total share of deficiencies, it was decided to consider them a unite category. Probabilities to occur will be much lower considering their limited confrontation by PSCO. The highest probability for other types of ballast water deficiencies to occur, combines middle aged multipurpose vessels of tonnage no more than 7500 GT:

$$\begin{aligned}
 P(\text{Others} \cap T2 \cap A2 \cap S1) &= P(O) * P(T2) * P(A2) * P(S1) \\
 &= 0.071 * 0.302 * 0.432 * 0.407 \\
 &= \mathbf{0.00377 \text{ or } 0.38\%}
 \end{aligned}$$

TYPE	AGE (Y.O.)	SIZE (GT)	(P)	(%)
General Cargo 0.302	0-9 0.31	0-7500 0.407	0.002705	0.27%
		7501-40000 0.302	0.002007	0.20%
		40000+ 0.291	0.001934	0.19%
	10-19 0.432	0-7500 0.407	0.00377	0.38%
		7501-40000 0.302	0.002797	0.28%
		40000+ 0.291	0.002696	0.27%
	20+ 0.258	0-7500 0.407	0.002252	0.23%
		7501-40000 0.302	0.001671	0.17%
		40000+ 0.291	0.00161	0.16%

Figure 13: Probability of different outcomes for General Cargo vessels (part)

The final figure will provide with the probabilities with the slightest chance to happen regarding the possible combination of characteristics leading to ballast water deficiencies. The table shows the tree probability for tankers in the case of other ballast water deficiencies. Tankers despite being considered as risky vessels for inspections, in ballast water they have not caused any serious threat. This is also encouraged by the fact that in the tankers category are considered both oil and chemical ones. Large tankers (T3 – S3) in their final stage of their life (A3), show the smallest sequence probability to occur to other for other ballast water deficiencies. The value is equal to smaller tankers, but of total GT over 7500:

$$\begin{aligned}
 P(\text{Others} \cap T3 \cap A3 \cap S3) &= P(\text{Crew}) * P(T3) * P(A3) * P(S3) \\
 &= 0.071 * 0.228 * 0.258 * 0.291 \\
 &= 0.001306 \text{ or } 0.13\%
 \end{aligned}$$

TYPE	AGE (Y.O.)	SIZE (GT)	(P)	(%)
<b>Tankers</b> <b>0.228</b>	<b>0-9</b> 0.31	<b>0-7500</b> 0.407	0.00233	0.23%
		<b>7501-40000</b> 0.302	0.001729	0.17%
		<b>40000+</b> 0.291	0.001666	0.17%
	<b>10-19</b> 0.432	<b>0-7500</b> 0.407	0.003247	0.32%
		<b>7501-40000</b> 0.302	0.002409	0.24%
		<b>40000+</b> 0.291	0.002322	0.23%
	<b>20+</b> 0.258	<b>0-7500</b> 0.407	0.001939	0.19%
		<b>7501-40000</b> 0.302	0.001439	0.14%
		<b>40000+</b> 0.291	0.001387	0.14%

Figure 14: Probability of different outcomes for tankers (part)

## **Chapter 7. Conclusions**

In this part we will finalise by providing the conclusions stemming from this research. We will summarise all the findings regarding the management of ballast water deficiencies by the PSC, after the ratification of the IMO convention, and discuss what the first results of the inspections show. Furthermore, scope for extended research on the subject of ballast water monitoring by the PSC will be provided, given its recent law enforcement.

### **7.1 Conclusions**

The main motive for conducting this research about ballast water was no other than the will to achieve a more sustainable and environmentally friendly shipping for the future. Ballast water, despite being an essential parameter in vessels for their stability for many years, it was never considered as a major threat for the marine environment. Yet, the problem of non-indigenous species introduction incidents had been reported in various regions of the world. The majority of those species are microorganisms, like the phytoplankton, that are transferred to other regions through the ballast water tanks. During the BWE, those organisms are released in new environments, many times altering the domestic animal food chain bringing consequences to the coastal businesses. As trade expanded, so did the problem of invasive species.

As the awareness regarding the evolving problem increased, IMO reacted and proceeded to the adoption of the International Convention for the Control and Management of Ships' Ballast Water and Sediments, in 2004. Scope of the convention has been to eliminate NIS and prevent them from adapting into new environments. However, the adoption of the convention only provided at the time instructions regarding the exchange of ballast water. The exchange should be performed in specific locations, were the organisms will have a lower chance to survive. A potential ratification of the convention will make it mandatory for all signing parties to follow the requirements as well as to install a BWMS. The D-2 regulation which has come into force, provided restrictions regarding the concentration of microorganisms in ballast water samples. This happened in 2016, when the 54<sup>th</sup> state agreed on the convention and exceeded the 35% tonnage representation by the signed states. Still, it will be given a period of 5 years for all owners to install such a system and for the crew to become familiarised, beginning from its enforcement date on 09/09/2017.

With vessels being subject to the D-2 regulation, owners will have to pay increased attention towards the BW management of their vessels. Depending on the year of construction, vessels will be performed survey renewals by the IOPPC, in order to be awarded with a certificate that will indicate the vessel's compliance with environmental regulations. Vessels that had their renewal survey prior 2017 and after 2014, are obliged to meet the requirements of the convention and have proceeded to the installation of a BWMS. Owners that had their renewal before 2014 or expect to have one until 2019, will have until 2024 to meet with the requirements. Moreover, all owners with expected new build vessels from 2019 and onwards, must reassure the compliance with the BWM convention in order to successfully receive the certificate. The goal for IMO is that by 2024, all vessels should be in accordance with the D-2

regulation of the convention in order for the D-3 and D-4 regulations to also be ratified. Vessels that have been approved for the certificate, will indicate a higher level of compliance and a reduced chance to be detained by the PSC.

Port State authorities were created by the UN agencies, in coordination with the international organisations, in the early 80s. Aim of the PSC authorities has been to ensure that incoming vessels are following the requirements implied in the international conventions. Any vessel not complying will be awarded with deficiencies, indicating that there is a problem with the vessel that must be immediately taken care of by the crew. Failing attempts to resolve the threat will result in the detention of the vessel. For the better monitoring of the progress of PSC, the creation of regional agreements was suggested by the IMO which resulted in the creation of the first MoU in Paris. Many other MoUs followed, covering all navigable regions and areas. All of the MoUs follow the same framework. As of 1995, the jurisdiction for determining which vessels should be inspected was given to every PSC authority. The creation of targeting matrixes has set the parameters for allowing the identification of HRS, which get prioritised when it comes to inspections. Some countries like the USA have developed their own framework for dealing with environmental compliance. The coast guard is responsible for the monitoring of vessels and inspections are subject to domestic laws that have been majorly inspired from the IMO conventions. Similarly, for ballast water the introduction of The First Rule in 2012 made the existence of a BWMS an absolute necessity for all vessels, those not compliant will be penalised. Selection of vessels is made based on a series Matrix tools used for determining risky vessels.

Given the enforcement, ballast water became a subject of inspection for all vessels. Even though the extension of BWMS installation applies, all vessels are obliged to follow the requirements mentioned in the annexes of the convention. Through the website of Paris MoU I was able to investigate the deficiencies awarded to vessels, and more particularly all the ones that are related to ballast water incidents. BWRB related deficiencies topped the list contributing 42.1% of the total deficiencies. Similar were also the results from the USCG Annual Report in 2017, with majority of deficiencies being related to ballast water records. Despite not being considered a dangerous type of vessel in the targeting matrixes, general cargo ships are found in most of the deficiencies. In addition, vessels between 10 and 19 years of age contributed a large amount to the final deficiencies as well as vessels of less than 7500 GT. The sequence of those characteristics were most commonly found in the paths of the probability tree, indicating that there is an increased likelihood for them to occur. Finally, in order to prevent making the trees complex in understanding, flag states and ROs were excluded as parameters given their evident collected data. The majority of penalised vessels were white - convenient flagged vessels and registered in a high performance RO, a result more or less expectable given the benefits they can secure. Goal of this thesis is to increase the awareness of the readers regarding ballast water management and contribute in the identification of suspect vessels. The limited data, available in combination with time constraints, allowed only the examination of generic parameters used for vessel targeting by Paris MoU.

All in all, this research was a first assessment from the results taken of the inspections made by the PSC of the Paris MoU. The final outcome provides the most noticeable probability sequences for ballast water deficiencies, given the vessels characteristics. Returning to main research question, which was formed in the first chapter, ballast water is a future major concern for the shipping community. The enforcement of the convention gave me ground to proceed in this research, given the mandatory

requirements that all vessels should meet regarding ballast water management. The PSC is the responsible authority for examining the level of compliance with the international convention, a responsibility originally assigned to the flag states. The targeting matrixes developed by the various MoUs, can identify the riskier ships based on their generic and historic parameters. With the present timeline for compliance of the convention, IMO foresees that by 2024 the D-2 regulation will be fully implemented, allowing the remaining performance standards (D-3 & D-4) to also be ratified.

## ***7.2 Suggestions for Further Research***

As mentioned, this research focuses on the generic parameters of the targeting profile of vessels. There is no doubt that this research would be even more complete if historic parameters were considered as well. This would be a more suitable research, given that the convention has already been in force for some years. The available data will be much wider this way, resulting in more recorded deficiencies and with different types as well. Comparison between the results of different MoUs could also be applicable. It could determine the effectiveness of each MoU's targeting system and how differently deficiencies are distributed.

A different type of research would include a further investigation on the BWMS. Deciding between the most suitable choices of systems is subject to different parameters such as the type microorganisms and the trade pattern of the vessel. Furthermore, the enforcement of the remaining performance standards, which are related to the requirements of the BWMS and the technologies applied to them, can provide an extra reason for someone to focus on those systems.

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