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Improving Port State Control (PSC) performance using a risk-based approach: An in-depth literature review

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Preface

I chose this topic because Port State Control (PSC) is a very important part of the globalized shipping industry. The importance lies in the fact that it is a very good tool for the shipping industry to check whether the shipping companies, but especially the companies' ships operate in accordance with international conventions (SOLAS, MARPOL, STCW, MLC).

In fact, due to my work in the field of inspections both in the company and on the ships, I found it interesting to do a more in-depth study on the ways that a shipping company can find to approach inspections through risk and to be able to reduce the remarks made during the inspections by the Port Authorities.

Acknowledgements

I would like to express my special thanks of gratitude to my professor who gave me the golden opportunity to do this project on the topic Improving Port State Control (PSC) performance using a risk-based approach: An in-depth literature review. Without his directions and feedback this thesis would not have been completed. Secondly, I would also like to thank my parents who helped me ethically and psychologically to complete my master studies.

ABSTRACT

During the past decades the economic contribution of the maritime transportation to the shipping industry has been increased rapidly. This is a positive trend, but it entails many threats (e.g. human life loose, environmental threats, sea pollution etc.) for the shipping industry. Therefore, a wide range of maritime measures have been created with the aim to eliminate the safety threats. Among these measures are included the Port State Control (PSC) inspections. Since the signature of the Hague Memorandum in 1978, the Port State Control (PSC) constitutes a strategy, that is implemented worldwide, with the aim to foreflight the substandard ships.

Considering the importance of the Port State Control (PSC) inspections, this is an in-depth literature review, which aims to identify the risk-based approaches that are proposed in the international literature for the improvement of the Port State Control (PSC) performance. In addition, this research aims to identify the factors that influence the (PSC) inspections based on the international literature. The sample of this literature review are 47 academic articles which have been published in high quality journals. A total of 28 papers identified which proposed risk-based approaches for the improvement of the Port State Control (PSC) inspections' performance. Additionally, a total of 19 papers were identified which examined the factors that influence the Port State Control (PSC) performance.

The research results, shown that most of the selected papers focus on the data driven Bayesian Networks (BN). Fewer studies have been published on other approaches such as on the Support Vector Machine (SVM) method, the Bayesian Networks (BN) and game mode and the K-nearest neighbor. As concerning the factors, which influence the Port State Control (PSC) inspections, the research results show that 17 out 19 researches, which examined in this Dissertation, focused on the following factors: the ship age, the ship flag, the inspection history and the classification society.

Key words: Port State Control (PSC) performance, risk factors on Port State Control (PSC), Paris MoU

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1.INTRODUCTION

During the past decades has been witnessed a rapid growth of the maritime transportation demand. This is a positive evolution, which shows the prospects of the global shipping industry. But, this growing trend entails some threats and risks for the shipping industry (e.g. ship collisions, oils spills, environmental pollution, property losses, etc.). Such threats and risks turned the attention of the researchers (Li et al., 2014; Yang et al., 2013; 2014; John et al., 2016; Pristrom et al., 2016; Zhang et al., 2016) to the investigation of issues related to the maritime safety and to the Port State Control (PSC) inspections. The aim of the Port State Control (PSC) is to help the port authorities to inspect vessels with the aim to minimize and prevent the maritime accidents as well as the illegal actions of the shipowners (Xu et al. 2007).

European and Greek shipping transportation is getting way ahead in making themselves globalized. But the accidents that occur can cause damage to marine environment. To improve the situation Port State Control (PSC) inspection is developing and is adapting to the risk management approach to deal with marine safety to a greater extent. The first memorandum of understanding (MoU) on Port State Control (PSC) was established in Europe in 1982 and is known as "Paris MoU" (EMSA, 2020).

The basic concept of Port State Control (PSC) is that the state of the port has the right to inspect the coming ships from a foreign territory in order to ensure that they will not cause threats to the maritime safety (Li and Zheng, 2008). With the help of the International Maritime Organization (IMO) and the International Labor Organization (ILO), the numbers of MoU are increasing worldwide, and the standards of the Port State Control (PSC) are also enhancing through the risk management approach.

Taking into account the importance of the Port State Control (PSC) inspections in the implementation of the international safety standards by the shipping industry as it has been highlighted by many researchers (Knapp & Franses, 2007a, Knapp & Franses, 2007b, Knapp & Franses, 2007c, Knapp & Franses, 2008, Knapp & Franses, 2009, Payoyo, 1994, Fu et al., 2020, Yan & Wang, 2017, Tsou, 2019), the aim of this Dissertation is to provide an in-depth literature review on the risk-based approaches of the Port State Control (PSC) inspections. Consequently, this Dissertation presents and analyzes the research results of past and contemporary researchers (Gao et al, 2008, Xu et al., 2007) Hänninen & Kujala, 2012; Goerlandt & Montewka, 2015; Zhang et al., 2015, Banda, O.A.V. et al., 2016; Zhang et al., 2013; Hänninen et al., 2014; Wu et al., 2015,

Lehikoinen et al., 2013) who proposed risk-based methodologies with the aim to improve the performance of the Port State Control (PSC) inspections. Furthermore, this Dissertation examines the factors, that influence the performance of the Port State Control (PSC) inspections, by examining the research results of relevant researches (Knapp & Franses, 2007a, Knapp & Franses, 2007b, Knapp & Franses, 2007c, Knapp & Franses, 2008, Knapp & Franses, 2009, Payoyo, 1994, Fu et al., 2020, Yan & Wang, 2017, Tsou, 2019). The examination of the factors, which influence the performance of the Port State Control (PSC) inspections is important because they are considered by the researchers who have developed the risk-based approaches for the improvement of the Port State Control (PSC) inspections.

The research problem is significant because the international literature lacks studies which carry out statistical analysis on the effectiveness of the Port State Control (PSC) inspections. Nevertheless, the researchers acknowledge that the international literature is rich of studies which examine why the Port State Control (PSC) inspections are necessary and thus should be implemented in the shipping industry (Carriou et al., 2008). Additionally, the problem is significant due to the importance of the Port State Control (PSC) inspections to the maritime safety. Due to the existence of a wide range of risks, which are associated with the shipping industry, the governments and the global shipping industry try to reduce the potential disasters.

To fulfill the research objective, the in-depth literature review was chosen as a research methodology. The sample of this literature review are 47 academic articles which have been published in high quality journals. The related academic articles were accessed from the Google Scholar. The search generated a total of 28 papers which proposed risk-based approaches for the improvement of the Port State Control (PSC) inspections' performance. Additionally, a total of 19 papers were identified which examined the factors that influence the Port State Control (PSC) performance. The basic criterion, that the researcher considered in order to select the academic articles, is their relevance to the research objective.

This Dissertation is consisted of eight chapters. The first chapter is the introductory chapter. The second chapter provides a general overview on the shipping industry and Port State Control (PSC). More specifically, in this chapter the historical development and the definition of the Port State Control (PSC) are provided. In addition, in the same chapter, are presented: the types of the Port State Control (PSC) inspections, the Paris MoU and the MoUs implemented worldwide as well as the European Port State Control (PSC) regime. Finally, the chapter presents some important

research findings on the effectiveness of the Port State Control (PSC) inspections. The third chapter presents the research methodology. The fourth chapter presents the in-depth literature review on Port State Control (PSC) risk-based approaches. The fifth chapter presents the factors, which influence the performance of the Port State Control (PSC) inspections. The six chapter presents some quantitative methods on Port State Control (PSC) risk management. The seventh chapter analyzes and critical evaluates the research findings of the in-depth literature review. The eighth chapter provides the conclusions. The Dissertation is completed with the future research opportunities and with the research limitations.

2. SHIPPING AND PORT STATE CONTROL (PSC)

2.1 HISTORICAL DEVELOPMENT AND DEFINITION OF PORT STATE CONTROL (PSC)

According to IMO (2020) Port State Control constitutes a regime that concerns the ship's inspections. IMO (2020) states that the aim of the Port State Control as an inspection of foreign ships in the national ports entails the verification of the ships' conditions based on international law. The role of the inspectors is crucial to the Port State Control as they have the duty to investigate if the ships comply with the provisions of the international conventions including SOLAS, MARPOL, and others (IMO, 2020). Based on ships' risk profiles, inspectors should also grip the data on risk-based approaches. For more frequent and more detailed inspections, immediate severe detentions are required such as off-hire detentions (Galvan & Galvan, 2017).

One of the most important aims of Port State Control (PSC) is to check for the performance of oil all over international ports. This is highly sensitive because a small mistake in it would lead to the loss of millions of dollars. We need to understand the depth of this issue. Port State Control (PSC) check for the maximum capacity of tanks. How to fill them properly, how much distance oil tankers will have to travel what are the precautionary measures that are to be taken during its transportation. Port State Control (PSC) also looks for equipment in emergencies. Port State Control (PSC) also has to look for the weather forecast for safe transport. All the possible measures should be ensured because a small mistake would lead to bigger consequences (Trbojevic, 2013).

The Port State Control incorporates the review of ships' certificates and the psychical review of the ships. The Port State Control is identified in the ILO arrangements. Based on the principles of the international shipping law, the states are eligible to exert Port State Control on their ports. By examining, the historical roots of the port stated control, it can be concluded that this control is laid down in international conventions of the shipping industry. For example, the International Labor Organization during 1976 developed and adopted an international convention which concerned the Port State Control. This convention defines that Port State Control is a procedure, which aims to protect the shipping industry, by preventing accidents that have negative impacts on human lives and, on the environment (Bello, 1994).

One accident that invoked global concerns took place during 1974. During this period, Torrey Canyon released 100,000 tons of oil into the sea. This devasting accident shocked the global public

opinion and the world governments. Thus, two years later, the governments all around the world agreed to sign the International Convention on Civil Liability for Oil Pollution Damage. The aim of this convention was to prevent sea disasters that may be caused by the shipping industry. But, in March 1978, another severe accident happened again. During this period Amoco Cadiz released approximately 230,000 tons of oil off the coast of Brittany. This accident had devastating environmental effects on the sea. Additionally, this accident caused important economic losses in national economies. The disaster cost almost 290 million US dollars (Thomas & Reed, 1998).

The economic losses can be attributed to a variety of factors. For example, the accident caused an important loss of the vessel, the accident caused important legal and research costs, the accident caused damages to human health. Furthermore, the economic effects of the accident are a result of the immediate emergency response, the environmental restoration activities, and the loss of personal property. Based on the aforementioned data and experiences, it can be concluded that the spill oils have a severe impact not only on the environment but also on the human lives and on the national economies. National economies need much time in order to recover from a spilled oil. Therefore, since then international bodies have undertaken a wide range of actions in order to prevent the devastating effects of the accidents that occurred in the sea. Today, international organizations such as IMO have realized that sea accidents demand proper management and immediate response (Thomas & Reed, 1998).

Thus, in 1948, the governments decided to sign the International Convention on Safety of Life at Sea. From this, it can be concluded that the losses of life in the sea are a matter of global concern since 1948. Accordingly, IMO in 1974 published conventions relevant to the Port State Control. In addition, the OECD publishes a document relating to the control of flag-of-convenience ships. Such documents help governments all around the world to address challenging situations that occurred by the inadequate existence of Port State Control. At this point, it is important to clarify that both the Maritime Safety Committee and the IMO concern with the control of the ships' flags with the aim to prevent the ships that do not operate according to the global safety standards.

In this regard, the Maritime Safety Committee has developed procedures which concern the flag control based on the international convention for the safety of life at sea. In 1975 IMO adopted the recommendations as proposed by the Maritime Safety Committee. This adoption is reflected in the Resolution which developed during 1975. All these conventions have a provision which regulates the problems relevant caused by substandard ships. More specifically, based on the global

conventions' initiatives the port authorities have the right to inspect the ships' flags on their ports. These inspections give the port authorities the opportunity to undertake the necessary steps in order to prevent shipping hazards (Abuja, 1995).

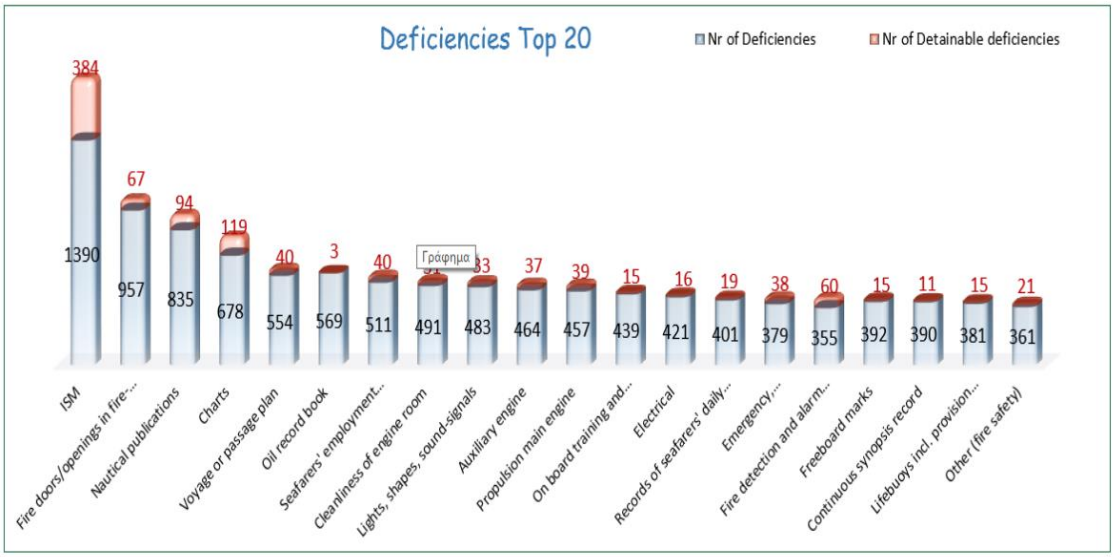
2.1.1 TYPES OF PORT STATE CONTROL (PSC) AND DEFICIENCY CRITERIA

In this chapter, we analyze the types of Port State Control (PSC). It is important, to begin with, the fact that each Port State Control (PSC) inspection is conducted based on Annex 10 of the Paris MoU. The inspections types are four and they are described below. The first inspection type is the initial inspection. The second type is the more detailed inspection, the third type is the expanded inspection and the final type is the concentrated inspection campaign. The initial inspection includes the visits on the ship's board which aims to detect deficiencies in operations. In addition, the initial inspection aims to check if the ships comply with the standards of the Paris MoU as they are listed in Annex 10. Furthermore, the aim of the initial inspection is to check the hygiene condition (Toliopoulos, 2015).

The aim of the detailed inspection is conducted when there is clear evidence that the ship does not comply with international shipping standards. This type of inspection occurs when the Port State Control (PSC) officers have evidence that proves that the ship is substandard. The detailed inspection includes the documentation, the structural condition, the emergency systems, etc. The expanded inspection is another type of inspection which aims to check the overall conditions and performance of the shipping vehicle. The risk areas of the expanded inspection are the following: the documentation, the Structural condition, the Water/Weather tight condition, the Emergency systems, the Radio communication, the Cargo operations, the Fire safety, the Alarms, the Living and working conditions, the Navigation equipment, the Life-saving appliances, the Dangerous Good, the Propulsion and auxiliary machinery, the Pollution prevention (Toliopoulos, 2015). It is important to highlight that during the expanded inspection, the inspectors consider all the elements that are being included in the international documents (ILO, ISM, STCW). Finally, the aim of the concentrated inspection campaign is to investigate specific areas which may include deficiencies. This is a very important type of shipping inspections. This type of inspection usually occurred over a period of three months and covers a wide variety of topic included: the

Fire Safety Systems, the Structural Safety and Load Lines, the Safety of Navigation and other. Figure 1 depicts the most common detainable deficiencies in 2017.

Figure 1: Most common detainable deficiencies during 2017



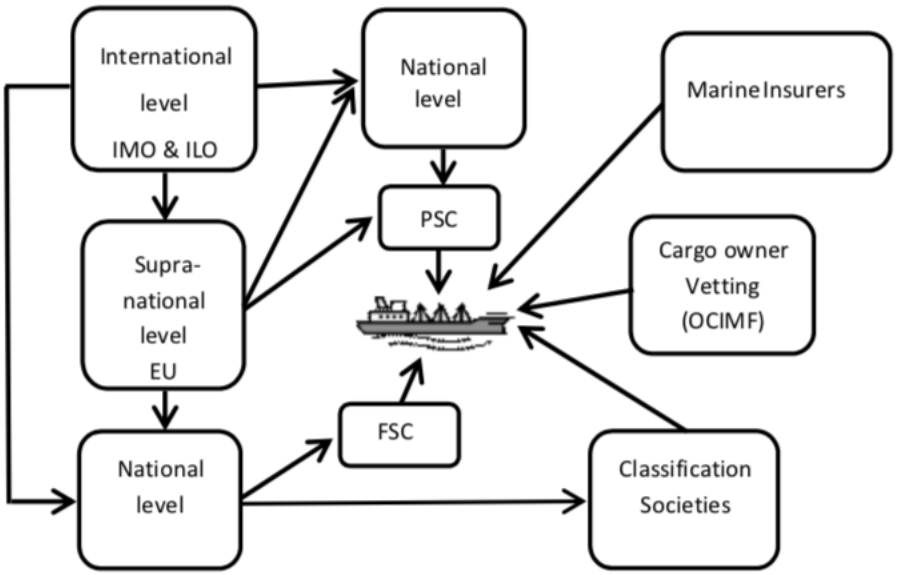
Source Toliopoulos (2015)

2.2 PORT STATE CONTROL (PSC) IN THE SHIPPING INDUSTRY

Contemporary researchers (Roe, 2009, Black, 2008) recognize the complicated role of the modern shipping industry. This complicated role can be attributed to its' polycentric governance. More specifically, Roe (2009) explained that the shipping industry is fragmented as the state is not the only local authority that have the responsibility for the shipping inspections. In addition, Black (2008) complements that in the shipping industry a wide range of sub-contractors, who depend on each other, need to collaborate during the shipping inspections. Thus, Black (2011) argued that the shipping industry has a multi-level control that make its' structure rather than complicated. Figure 2 shows the multigovernmental shipping industry.

Based on the figure 2, it can be concluded that the safety and security are susceptible to the flag state control (FSC) and to the Port State Control (PSC). A wide range of national, international and global bodies (United Nations, IMO, European Union) are involved in the Port State Control (PSC) of the contemporary shipping industry. Furthermore, figure 2 shows, that a wide range of private actors (e.g. oil companies), are involved in the management of the shipping industry's safety and security.

Figure 2 Maritime governance with public and private organizations and the coupling to a vessel

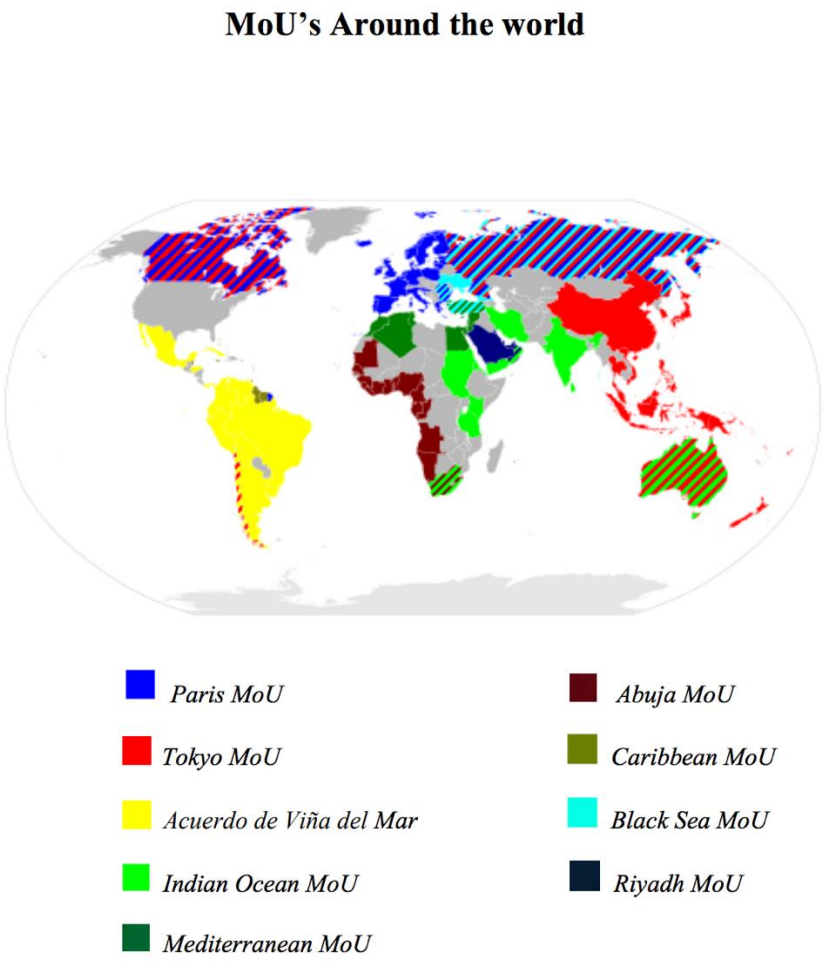


Source Roe (2009)

2.3 MoU's IMPLEMENTED WORLDWIDE

Worldwide there are a wide range of regional MoU's which concern the Port State Control (PSC) inspections. All these MoU's (figure 3) are based on the Paris MoU. In this chapter, are presented the global MoUs (Tokyo MOU (Pacific Ocean), Acuerdo Latino or Acuerdo de Viña del Mar (South and Central America), the Caribbean MOU, the Mediterranean MOU, the Indian Ocean MOU, the Abuja MOU (West and Central Atlantic Africa), the Black Sea MOU, and the Riyadh MOU (Persian Gulf) as well as the Paris MoU.

Figure 3 MoUs around the world



Source Toliopoulos (2015)

2.3.1 THE PARIS MoU

The Port State Control legislation of the European Union is based on the Treaty of Rome (1957, articles 75-84). During the Hague meeting in 1978, a memorandum was agreed with the aim to establish the safety conditions of the board vessels in the European Union. Additionally, this memorandum aimed at the audit of the labor conditions of the board vessels converges with the international regulations of ILO.

A major shipwreck was the cause that leads to the development of a mechanism that would check the suitability of ships. This shipwreck concerns the VLCC ', Amoco Cadiz'. On March 16 1978 the Amoco Cadiz, a Liberian-flagged ship, ran aground off the coast of Brittany, France. The ship eventually broke into three parts and sank, creating the largest oil pollution to date. This has caused unrest in the political and social spheres of France. Therefore, stricter measures were being taken with regard to maritime safety. In 1982 a MoU was signed in Paris. The aim of the Paris MoU was to cover a larger scope of conventions and regulations. The Paris MOU is considered as the beginning of the Port State Control (PSC) inspections in the European Union ground. In 1998, Europe published several Council Directives in order to develop the right legal framework that will harmonize the European Union legislation with the Paris MoU. For the time being the Paris MoU is lead on the European's Union Directive 2009/16/EC, which established by the European Parliament. Totally, 26 countries have participated in the Paris MoU since its' establishment in 2009 (Mitroussi, 2004).

The mission of the Paris MoU is to help the states to diminish the operation of sub-standard ships in its area of responsibility. In order to achieve its' mission, the Paris MoU introduced obligatory shipping inspections in the ports. Until 2013, approximately 19,000 inspections had been carried out on the grounds of the European Union. The inspections are based on a harmonized system.

One of the major goals of the Port State Control (PSC) inspections, that established by the Paris MoU, is to provide the local authorities the ability to check foreign ships as concerning their compliance with the international rules and regulations. Such regulations concern the sea safety, the safety of life at sea, the pollution of the environment, etc. The MoU does not pose limits on the ship owners to comply with the international safety requirements (Paris, MoU, 2014).

The instruments of the Port State Control (PSC) inspections as defined by the Paris MoU are based on international conventions and on the Maritime Labour Convention. The wide variety of the involved instruments revealed the complexity of the PCS inspection system (ILO, 2015, Paris MoU, 2014).

The basic parts, that define the functionality of the Paris MoU are described in the following paragraphs. The first part of the MoU is "clear grounds". The clear grounds established that the ship inspector should take relevant action of the ship or the equipment of the ship do not comply with the international regulations and conventions. In addition, based on the clear ground introduce a major dimension of the vessel legislation. This is the flag state. The flag state has the right and the responsibility to verify that vessels flying its flag comply with international regulations (Paris MoU, 2014).

The other important part of the Paris MoU is the "name and shame". The name and shame strategy has to do with the vessels that not comply with the regulations as developed by MoU or by other international conventions. This strategy recognizes the role of classification societies. The shipping companies, flag states, and classification societies should work in order to achieve higher compliance with international laws, regulations, and conventions (Paris MoU, 2014). "White, grey or blacklist" of flag states is also an important part of the Paris MoU. This element is closely related to the publication on white, grey, and blacklists (Paris MoU, 2014d). White, grey or blacklist introduce the idea that the flag performance which is established on an annual basis should consider the inspection and detention history of the vessels, that took place over the last three years. Based on the grey or blacklist of the flag, the performance of each vessel is checked and then presented on a list. This list marks the ships as white, grey or black. The white flag means that the ships have a good performance but on the contrary, the black flag means that the ships have bad performance (Paris MoU, 2014d).

The "performance profile" is another important element of the Paris MoU. Based on this element all the ships should pass from performance calculations, which are calculated by ISM companies and by certified global organizations. The performance profile of the ships should be calculated as high, medium, low, and very low. For the performance calculations, global organizations consider the history of the ships during the last three years. (Paris MoU, 2014d). The risk profile of the ships is another element of the Paris MoU. The risk profile should be white, grey, or black. This profile is calculated based on a wide range of criteria. These criteria include the age of the vessel, the type

of the vessel, the performance flag, and the inspection history. Based on the risk profile a ship is recognized as high risk (HRS), standard risk (SRS) or low risk (LRS) ship (Paris MoU, 2014d). Paris MoU established "priority" as another important element of its' regulations. This element states that the prioritization of the ships' inspections should be based on their risk profile. Therefore, periodic inspections take place from time to time based on the ships' risk profile. The categorization of the ship's risk profiles can be Priority I (PI), Priority II (PII), or no priority. The vessels that belong in the third category are not considered as being eligible for inspections unless they are not violate the "clear grounds" criterion (Paris MoU, 2014).

Finally, the "inspection types" are another important element of the Paris MoU. The "inspection types" established specific categories of ships' inspections. Based on the "inspection types" there are three types of inspections. The first type is the initial inspection. The second type is the more detailed inspection and the third type is the expanded inspection.

At this point, it is important to make a critical evaluation of the Paris MoU. When Paris MoU introduced it received much negative feedback concerning its' implementation. Many scholars (Bloor et al., 2006, Özçayır, 2009, van Leeuwen, 2016, Bijwaard & Knapp, 2009) perceived it a being discriminatory. But nowadays, many scholars argue that the Paris MoU is effective and ensures the implementation of the international legal system. In addition, scholars (Bloor et al., 2006, Özçayır, 2009, van Leeuwen, 2016, Bijwaard & Knapp, 2009) argue that today there is sufficient evidence that Paris MoU has contributed to the prevention of sea pollution and to the enhancement of sea standards.

2.3.2 OTHER MoU's IMPLEMENTED GLOBALLY

Expect from the Paris MoU, there are also other regional MoU's worldwide concerning the implementation of the Port State Control (PSC) inspections. One MoU is the Tokyo MoU. Its' aim is to diminish the substandard shipping in the Asia-Pacific region. In addition, this MoU aims to promote and implement the global application of the IMO/ILO principles on the Port State Control (PSC) inspections. The vision of this MoU is to develop a Port State Control (PSC) regime in the Asia-Pacific region which is effective. Thus, in the context of this MoU many collaborations have been developed (Toliopoulos, 2015).

The Latin American Agreement on Port State Control of Vessels is also a well-known MoU. This MoU is considered as an important international attempt for the improvement of the operational agreements between the states. Indian Ocean MoU is based on the International Maritime Convention. Its' aim is to ensure the safety of the maritime infrastructure. In the context, of this MoU, many regional collaborations have been developed. Mediterranean MoU constitutes an international effort which aim to ensure maritime safety by preventing sea pollution. This MoU was developed in 1995 in the Euro-Med conference. In 1997 many countries joined the Mediterranean MoU including Algeria, Cyprus, Egypt, Israel, Malta, Morocco, Tunisia and Turkey (Toliopoulos, 2015).

The Abuja memorandum is another MoU which implemented in Nigeria. This MoU developed the principles under which the countries of the ports of the region should operate. Since the implementation of this MoU, many countries (Angola, Benin, Cameroon, Cape Verde, Congo, Cote d‟ Ivoire, Gabon, Ghana, Guinea, Equatorial Guinea, Liberia, Mauritania, Namibia, Nigeria, Senegal, Sierra Leone, South Africa, Sao Tome and Principe, Democratic Republic of Congo, Guinea Bissau, The Gambia, and Togo) of the region have managed to improve the safety of their shipping industry (Toliopoulos, 2015).

Black Sea MoU developed during 2000. The aim of this MoU is to improve the Port State Control (PSC) of the countries that have joined it. Based on the principles of this MoU, the Port State Control (PSC) inspections in the Black Sea Region should be implemented by qualified port state inspectors and authorities. Finally, Riyadh MoU, which developed in 2004 aims to improve the Port State Control (PSC) in the following regions (Bahrain, Kuwait, Oman, Qatar, Saudi Arabia and UAE). This MoU is an agreement signed between the countries of the region with the aim to ensure the safety, security and efficiency of the shipping industry (Toliopoulos, 2015).

2.4 THE EFFECTIVENESS OF THE PORT STATE CONTROL (PSC)

Carriou et al. (2008) argued that international literature lacks studies that carry out statistical analysis on the effectiveness of the Port State Control (PSC) inspections. Nevertheless, the researchers acknowledge that the international literature is rich in studies that examine why the Port State Control (PSC) inspections are necessary and thus should be implemented in the shipping industry. For instance, Kasoulides (1993) conducted a research in order to examine how the implementation of the flag state control managed to eliminate the problems that occurred by the proliferation of open registries. Additionally, Kasoulides (1993) examined the role of the rights of the coastal states in accordance with the flag inspections.

Accordingly, Ozcayir (2001) examined the important role of the ISM Code as well as the influence of the Erika incident in the development of the European Port State Control (PSC) system. Additionally, Clarke (1994) examined the flag state control and concluded that the ineffectiveness of this regime leads the coastal states to take alone the necessary steps in order to protect their coasts from the maritime accidents. Furthermore, Kiehne (1996) examined the availability of the sanctions to Port State Control (PSC) authorities. The researcher examined the phenomenon by considering that the inspections of the foreign ships have a wide variety of instructions concerning the deficiencies.

Cuttler (1995) examined the Port State Control (PSC) inspections in accordance with the ships' sources that cause environmental pollution. Upon the completion of the research, the researcher recommended to the states to examine the related benefits of the proactive policies and frameworks in regard to the Port State Control (PSC) inspections. Hare (1997) is another researcher, who examined the effectiveness of the Port State Control (PSC) inspections. The researcher concluding that the development of several regional MoUs has a positive impact on the shipping industry. More specifically, the researcher asserted that the regional MoUs contributed to the elimination of the substandard ships, which aspire to take part in the international shipping commerce.

Hare (1997) is one of the first researchers who contribute to the literature which explores the effectiveness of the Port State Control (PSC) inspections. Accordingly, McDorman (2000) is another important researcher who investigated how the regional PORT STATE CONTROL (PSC) agreements contributed to the development of a harmonized inspection regime. As McDorman (2000) argued the harmonized inspections procedures managed to level the playing field that exists

between the different ports. Owen (1996) focused his research on the examination of the effectiveness of the Paris MoU. The researcher concluded that the Paris MoU has a lot of limitations that prevent the effectiveness of the Port State Control (PSC) inspections. More specifically, Owen (1996) elaborating on his opinion by stating that the Paris MoU did not give to the port states the authority to control and influence the design and the construction of the ships. Nevertheless, Odeke (1997) research proved the effectiveness of the Port State Control (PSC) for the UK shipping industry. More specifically, the researcher argued that the Port State Control (PSC) has managed to reduce and prevent the environmental pollution caused by the ships. Between 1993 and 1994 published two important researches concerned the effectiveness of the Port State Control (PSC) inspections.

Bell (1993) argued that the flag state inspections in the UK have contributed to the elimination of the burden which concerns the international ships' standards. In the same manner, Payoyo (1994) attempted to assess the Port State Control (PSC) regime by using statistical analysis. The researcher collect data and analyzed the annual statistics which had been generated by the implementation of the Paris MoU for the years 1982-1992. An interesting finding of the research conducted by Payoyo (1994) is that the researcher revealed that despite the existence of the Port State Control (PSC) regime in the shipping industry still exist ships that operate without international standards. The research also found that the collection of the baseline data of the ships, which have been categorized as being substandard, increase the effectiveness of the Port State Control (PSC) inspections. The same research finding revealed by Mejia (2005) research. The researcher concluded that the ISM Code has a positive impact on the Port State Control (PSC) inspections. Nevertheless, the researcher asserted that the lack of empirical statistical data prevents the effectiveness of the Port State Control (PSC) inspections.

A research conducted by Carriou et al. (2008) used Poisson models in order to estimate the effectiveness of the Port State Control (PSC) in the shipping industry. The estimates, that occurred from the Poisson models revealed that the basic factors that can predict the effectiveness of the Port State Control (PSC) are the following: the ship's age, the ship type, and the flag of registry. In addition, another important finding of Carriou et al. (2008) research is that after a Port State Control (PSC) inspection the reported ships' deficiency is diminished by 63% until the next inspection.

2.5 THE PORT STATE CONTROL (PSC) REGIME IN EUROPE

Port State Control was first developed in Europe when the Liberian oil tanker was breaking into three pieces and more than 220.00-ton oil were spread in the sea. It was the start of Port State Control. Now it has been taken as to be quite effective on the boarding of ships and it also involves some of the international instruments on the safety and security of the ship and avoids it from marine pollution (EMSA, 2020).

Europe's coastline has almost 1,000 ports. These ports as used by the member-states in order to manage 90% of their external trade and 40% of the European Union's trade. It is worth saying that almost 3,5 billion tonnes of goods and 350 million passengers are being transported through the European coasts annually. The aforementioned data make us to argue that it is important for the European Union to handle effectively its' maritime transport. This means that the European Union should take all the necessary steps in order to ensure that maritime transportation is operating in a secure and safe environment.

The European Commission has been involved in the development of the Port State Control regime since 1993. European Union has specific legislation in order to protect the shipping industry and to force it to operate by using international standards. In this context, the Port State Control Directive 2009/16/EC aims to ensure the compliance of the European shipping industry with international conventions and legislation. Furthermore, the Directive (EU) 2017/2110 aims to provide a mandatory system for port inspections. Accordingly, Directive 2009/16/EC was also developed in order to provide a mandatory system for port inspections.

EMSA is an international organization that has the duty to provide technical support and monitoring of Port State Control in the territory of the European Union. This means that EMSA has the obligation to assess the port state inspections which take place in the territory of the European Union. Such port state inspections are developed by the member-states based on their national regulations.

Furthermore, the European Union law foresees the obligatory risk assessment of the ships based on global statistical data. Several risk assessment studies help the European Union to improve the Port State Control performance. Additionally, there are national agencies which have the duty to support the Port State Control system. The duties of the agencies are the following: to give

technical support to the Commission and to the member states for the implementation of the Directive 2009/16/EC, to provide the states with support and training activities, to provide Europe and member states with statistics and other relevant information, to collaborate with the IMO, the ILO and Paris MoU, to cooperate with the member states in order to implement the information system (THETIS), to develop a harmonized community scheme and to organize training on the Port State Control (EMSA, 2020).

European Union uses THETIS database in order to increase the efficiency of its' inspections. This data-based has been developed by EMSA. Furthermore, it is worth saying that this databased developed based on the Directive 2009/16/EC, Directive 2009/17/EC, Directive 2009/15/EC, and Directive 2009/20/EC. THETIS is a platform that is constantly improved and updated in order to support the changes that the European Directives bring to Port State Control (PSC) regime. In summary, THETIS platform is an information system that is based on port information and data from the inspections. This information system has been developed in such a manner in order to be able to guide the ship users based on a risk approach. Additionally, THETIS system can generate reports that are available to the port authorities of the European Union. Up to date, more than 18,000 inspections are taking place every year based on THETIS informational system. In addition, almost 600 authorized ship authorities join the system. THETIS database is integrated with other European databases too (e.g. EU-classification societies, Equasis, and other (EMSA, 2020).

3.METHODOLOGY

3.1 Research Design

Kazdin (2017) explains that research design acts as a manual to direct the researcher when fetching data for analysis and interpretation purposes. The basic aim of the research design is to assist the researcher to develop a framework in order to solve the research problem. The research design included the following parts. First, the researcher should identify the research problem. The research problem of the current research is to explore the Port State Control (PSC) performance using a risk-based approach. Secondly, the researcher should read the relevant literature on the matter under-investigation. Then the researcher should select his methodology in order to address the research problem.

3.2Sample

Since the introduction of the Port State Control (PSC) regime in 1982 many researches have been published. The research interest on the improvement of the Port State Control (PSC) inspections is increased through the years. This is an in-depth literature review, which aims to identify the risk-based approaches that are proposed in the international literature for the improvement of the Port State Control (PSC) performance. In addition, this research aims to identify the factors that influence the Port State Control (PSC) inspections based on the international literature.
The sample of this literature review are 47 academic articles which have been published in high quality journals. A total of 28 papers identified which proposed risk-based approaches for the improvement of the Port State Control (PSC) inspections' performance. Additionally, a total of 19 papers were identified which examined the factors that influence the Port State Control (PSC) performance.

The basic criterion, that the researcher considered in order to select the academic articles, is their relevance to the research objective. The research objective is to conduct an in-depth literature review on Port State Control (PSC) performance using risk-based approach. Only relevant journal articles were selected which contained information about the under-investigation issue. Other journal articles, which didn't have the required information, were not chosen.

In addition to it, relevant keywords were utilized for researching and finding these journal articles. By focusing on the previous data related to the particular topic of the Port State Control (PSC) performance in depth literature review has been utilized.

3.3In-depth literature review as a research methodology

In order to meet the research aim, an in-depth literature review was chosen as a research methodology. The research for the collection of academic articles was conducted on the database of Google Scholar. The academic articles, that were chosen, have been published in reputable scientific journals during the past 10 decades.

Some criteria were set for the selection of the articles that were studied. The first basic criterion was the date of publication of the article. The second criterion set for the selection of articles was the quality of the research and the scientific journals that published the articles.

An effective and well-conducted in-depth literature review as a research method creates a solid foundation for advancing knowledge and facilitating the development of new theories on a scientific field (Webster & Watson, 2002). By evaluating findings and perspectives from many empirical findings, a systematic literature review can provide holistic answers to a research question. A systematic literature review can also help the researcher to identify gaps in scientific knowledge about a topic. In addition, an in-depth literature review is an excellent way of synthesizing research findings to identify areas in which more research is needed. The discovery of such areas is crucial for the creation of theoretical frameworks and the construction of conceptual models (Tranfield et al., 2003).

At this point, it is important to note that the in-depth literature review requires a more rigorous approach compared to most other types of literature review (e.g., narrative literature review) (Whittemore & Knafl, 2005).

4. IN-DEPTH LITERATURE REVIEW

4.1RISK BASED APPROACHES

Port State Control (PSC)) inspection is one mechanism with major importance for the shipping industry. This is because Port State Control (PSC) inspections help the states to protect the maritime safety and to develop a framework that ensures the safety and the security of the shipping industry. Due to the important role of the Port State Control (PSC) inspections, many researchers have conducted studies which provide risk-based approaches that can enhance the Port State Control (PSC) performance. The aim of this chapter is to provide relevant research findings which concern the most used risk-based approaches for the enhancement of the Port State Control (PSC) performance.

Based on the in-depth literature review, during the years differed risk-based approaches have been developed with the aim to improve the Port State Control (PSC) performance:

- Support vector Machine (SVM)
- K-Nearest Neighbor
- Data-driven Bayesian networks (BN)
- Bayesian (BN) and game model
- Port State Control (PSC) Ship-Selecting Model Based

4.2SUPPORT VECTOR MACHINE (SVM)

The first studies on Port State Control (PSC) performance based on a risk-based approach published in 2003 and in 2004. More specifically, Shen (2003) and Yang (2004) proposed a risk-based approach to assess the risk of Port State Control (PSC) systems. In addition, Kara (2016) used the weighted points method in order to evaluate the level of the risk that each vessel experiences during the Port State Control (PSC) inspection. The basic disadvantage of the risk-based approach provided by Shen (2003), Yang (2004) and Kara (2016) is the subjectivity of the expert judgments. This subjectivity may influence the results. Xu et al. (2007) attempted to address the issue of subjectivity, which detected in the weighted points method, by proposed a risk-based approach known as Support Vector Machine (SVM). This method proposed that the risk of candidate's vessels can be assessed based on previous historical data generated by onboard inspections. Xu et al. (2007) used the Support Vector Machine (SVM) in order to classify the

candidate vessel into specific categories of risk (high risk, low risk).

Since Xu et al. (2007) introduced the Support Vector Machine risk-based approach to improve Port State Control (PSC) performance, three researches (Zhong et al, 2008, Gao et al., 2008, Knapp & Franses, 2007), which published during 2007- 2008, adopted this approach.
As Xu et al. (2007) explain Support Vector Machines (SVMs) are administered learning models that use related learning calculations that break down data and perceive designs. The essential Support Vector Machine (SVM) takes an arrangement of information data and calculate, for each given information, which of two conceivable classes shapes the yield, making it a non-probabilistic paired straight classifier.

Support Vector Machine (SVM) model have a comparable useful frame to ANN plus spiral premise capacities, both well-known data mining methods. Support Vector Machine (SVM) is a preparation calculation for taking in order and regression rule from data. Support Vector Machine (SVM) is an amazing algorithm of classification. Not quite the same as the traditional Hidden Markov Model as we; as Maximum Entropy Modeling which needs cautious component determination as they don't give techniques to consequently choose ideal highlights from a given list of capabilities order dependent on Support Vector Machine (SVM) has an ability to distinguish ideal highlights through the procedure of training. In a fundamental system of Support Vector Machine (SVM). Support Vector Machine (SVM) recognizes an ideal hyperplane to isolate preparing information into two classes, positive cases along with negative cases (Xu et al., 2007). Support Vector Machine (SVM) takes a system that boosts an edge among basic examples along with an isolating hyperplane. Precisely, Support Vector Machine (SVM) accomplishes high speculation even by preparing information on a high measurement. By and by, even for a situation data for training can't be directly isolated due to the presence of some noise and isolating straight hyperplane despite everything can be worked through permitting some misclassifications. Furthermore, by presenting a Kernel work, Support Vector Machine (SVM) grip non-straight element spaces, as well as do preparation thinking about mixes of more than one component. Support Vector Machine (SVM) is received to construct a hazard appraisal part through incorporate the 15 target highlights into a direct articulation (Xu et al., 2007).
A 15 vectors comparing to a proposed 15 objective variables for every competitor transport in data for training are determined. A function of regression in Support Vector Machine (SVM) is

prepared through estimations of these highlights. This Support Vector Machine (SVM) work is then practical for testing information. All things considered, it decides if a boat ought to be investigated since it has a high hazard. In spite of the fact that the help vector machine has indicated promising execution in numerous applications, a way toward learning a Support Vector Machine (SVM) classifier is effectively influenced through uproarious preparing information. Data points of noise focus for the most part discovery near a hyper-plane (Zhong et al, 2008). Last but not least, Gao et al. (2008) combined support vector machine and K-nearest neighbor approaches to develop a new risk assessment model. This model was able to cope with noisy data. Gao et al. (2008) method managed to improve the accuracy of the results. Finally, Knapp & Franses (2007) used the Support Vector Machine (SVM) approach and based on 183,819 Port State Control (PSC) inspection records, developed a regression model. This model helped the researchers to measure the impact of the PORT STATE CONTROL (PSC) inspection on the probability of casualties. All the methods, that investigated in this chapter have some limitations. For example, all the methods, cannot address the problem of the dynamic risk prediction, which occur in different environments.

4.3K-NEAREST NEIGHBOR

In 2008, Gao et al. (2008) proposed the K-nearest neighbor in order to improve the performance of the Port State Control (PSC). More specifically, Gao (2008) managed to combine the Support Vector Machine (SVM) risk-based approach proposed by Xu et al. (2007) and the K-nearest neighbor in order to improve the effectiveness of the risk assessment system by facilitating it to cope efficiently with noisy data. The method proposed by Gao et al. (2008) managed to improve significantly the Port State Control (PSC) results in terms of accuracy and reliability. The innovation of Gao et al. (2008) approach is that it presents a new risk-based approach on the Port State Control (PSC) inspections by offsetting the deficiencies of the Support Vector Machine (SVM) method. Gao et al. (2008) in their paper argued that the Support Vector Machine (SVM) approach on the one hand can estimate the ships' risk factors based on their generic factors and their history but on the other hand it cannot improve the performance of the Port State Control (PSC) inspections when noisy data occurred. Thus, the researchers managed to develop a risk-

based methodology in order to remove the noisy data and to extract new target factors that are important for the Port State Control (PSC) inspections.

Gao etl al. (2008) explained that the K-nearest neighbors or k-NN is a machine learning algorithm which can be used for both classification or regression. In this algorithm k nearest or most closely related (depending of various factor and distances in terms of machine learning) training examples are used to classify or find the value of the object depending on if we are using k-NN for classification or regression. k-NN does not have the global knowledge of the function meaning that it gives the results depending on only the k neighbors we provide it with. In case of a classification problem, the class is assigned which is most common among its k neighbors while in case of regression problem, average value of its k neighbors is assigned.

K-closest neighbor (K-NN) is an arrangement procedure that uses an adaptation of this same technique. It chooses in which class to put another case by analyzing some number the k in k nearest neighbor — of the most comparable belongings or neighbors. It checks the quantity of cases for each class, and allots the original case to a similar class to which the vast majority of its neighbors have a place. (Kesavaraj, 2013) K-nearest neighbor (KNN) technique is the generally full grown machine learning hypothesis initially proposed though the Cover as well as Hart in 1968. The KNN classifier chooses a class mark of test model dependent on its K neighbors that are private to it. Some test model is organized into a class that has an amplify number of models between its K private neighbors. By the comparison of Support Vector Machine (SVM) a KNN classifier despite everything has high arrangement correctness if there is set of training is available set. That additionally implies that KNN could also manage energetic information better. Though now is a right time expending during a classification of process. Be that as it may, K-closest neighbor along with help Support Vector Machine (SVM) is as yet two top execution techniques of machine learning for content order. In this manner, this paper utilizes KNN strategy to recover a capacity of Support Vector Machine (SVM) classifiers (Shen et al , 2003).

4.4DATA-DRIVEN BAYESIAN NETWORKS (BN)

The researches, which propose the data-driven Bayesian Networks (BN) as a risk-based approach to improve Port State Control (PSC) performance, are more (Hänninen & Kujala, 2012; Goerlandt & Montewka, 2015; Zhang et al., 2015, Banda, O.A.V. et al., 2016; Zhang et al., 2013; Hänninen et al., 2014; Wu et al., 2015, Lehikoinen et al., 2013) compared to the researches on the Support Vector Machine (SVM) approach and on K-nearest neighbor approach. A Bayesian network is a graphical model which presents dependencies between a set of variables. The Bayesian Networks (BN) as a methodology is ideal to predict the likelihood of an event's occurrence. Thus, such a network can present probabilistic relationships. Bayesian Networks (BN) are used as a tool to assess the maritime security. The Bayesian Networks (BN) use a wide range of selected evaluation factors based on the subjective experience. The Bayesian method is considered as an advanced method, which focus on the diagnosis and prediction of a risk (Akhtar & Utne 2014).

A wide range of researches (Hänninen & Kujala, 2012; Goerlandt & Montewka, 2015; Zhang et al., 2015, Banda, O.A.V. et al., 2016; Zhang et al., 2013; Hänninen et al., 2014; Wu et al., 2015, Lehikoinen et al., 2013), have revealed that the Bayesian Networks (BN) are ideal for analyzing the importance of risk and the interrelated factors that cause a risk. During the past decades the Bayesian Networks (BN) have been applied in the shipping industry to ensure maritime safety.

The publications on Bayesian Networks (BN) cover a wide range of topics. For example, some researchers Hänninen & Kujala, 2012; Goerlandt & Montewka, 2015; Zhang et al., 2015) use the Bayesian Network (BN) to estimate the occurrence of collisions that may happen between the ships. Other researchers (Banda, O.A.V. et al., 2016; Zhang et al., 2013; Hänninen et al., 2014; Wu et al., 2015) use the Bayesian Networks (BN) to assess the vessels navigational safety. Other researchers (Hänninen, 2014; Li et al., 2014; Antao et al., 2009) used Bayesian Networks (BN) in order to analyze the maritime accidents. Montewka et al. (2017) developed a risk-based vessel design based on the BN. Goerlandt & Montewka (2014) used Bayesian Networks (BN) to estimate the maritime accidents. All these topics, covered by the researchers, revealed the applicability and acceptability of Bayesian Networks (BN) by the maritime industry.

Yang et al. (2018) argued that an elective technique for Bayesian Networks (BN) development is to construct a system from information, to be specific information-driven methodology, which can extraordinarily lessen reliance on human specialists as well as now plus again increment the correctness of a model. In any case, an important weakness of information-driven methodologies is that a quantity of potential structures for a given issue develops super-exponentially by a number of utilized factors in a difficult space (Yang et al, 2018).

Therefore, a cluster of exertion has been produced using written works to lessen such difficulty. When in an inspection of Port State Control (PSC) the risk-based study presents its Bayesian Networks (BN) prevalence (for example bi-directional examination) over other hazard evaluation draws near, introducing a novel method to break down Port State Control (PSC) assessments for transport proprietors as well as port specialists. Whenever point data about a particular boat concerning a characterized hub is acquired, its boat proprietor/administrator or authority of a port that a boat visits could also utilize a model to assess a detainment likelihood of a boat in a forward hazard expectation. When a ship is confined, a proprietor administrator could also utilize it again to break down the most potential makes driving a detainment in a regressive risk-based finding (Wu et al., 2015).

Despite, the increasing use of Bayesian Networks (BN) in the shipping industry, Bayesian Networks (BN) have received much criticism. The most usual criticism of Bayesian Networks (BN) is that the mathematical model needs too much data in order to generate sufficient results that will enhance the performance of the Port State Control (PSC). Some of the data that are required by the BN is difficult to be found and collected. Yang et al. (2008) argued that such data most of the time are inaccessible. Furthermore, Yang et al. (2008), who is among the researchers, who criticize the BN, argued that the quick growth of the probability table makes the procedure of computation even more complicated. Last but not least, Mkrtchyan et al. (2015), argued that the mathematical models, that developed based on Bayesian Networks (BN) are time-consuming and complicated.

In order to address the limitations of Bayesian Networks (BN) some researchers proposed relevant solutions. For example, Li et al. (2014) proposed a logit model based on a logistic regression analysis. This model aimed to accumulate a large amount of data in order to predict the probability of occurrence of sea accidents. Li et al. (2014) manage to develop a maritime risk BN. Norman et

al. (2007) developed another effective approach based on BN. This approach used the doubly truncated Normal distribution. This method is effective as it helps to reduce the elicitation burden. Finally, other researchers (Min et al., 2011, Wisse et al., 2008, Vinnem et al., 2012) developed other approaches in order to address the insufficiencies and the barriers of the BN. For instance, the researchers (Cain 2001, Wisse et al. 2008) proposed function-based methods. Norman (2007) used the BNN to develop a novel approach. This approach is based on the normal distribution of the central tendency of the parental nodes. In addition, other researchers (Min et al. 2011) developed other methods in order to address the drawbacks of the BN.

An alternative to the Bayesian Network (BN) is the data-driven BN. Such networks are based on data and thus the approach is known as data-driven. This approach can diminish the dependence that exists in the judgments of the experts. Therefore, data-driven Bayesian Networks (BN) are considered more reliable and accurate. Nevertheless, data-driven Bayesian Networks (BN) have also drawbacks and insufficiencies. Thus, researchers have developed several approaches to address such drawbacks. The drawbacks are related to the complexity of independence relations. Despite, their drawback Bayesian Networks (BN) and data-driven Bayesian Networks (BN) are widely used in the shipping industry with the aim to assess the risk of the Port State Control (PSC). An example of the successful use of Bayesian Networks (BN) in the shipping industry is the following: the shipowners can use the Bayesian Network (BN) based on Port State Control (PSC) model with the aim to analyze the probability of the ship's risk prediction. Furthermore, the Bayesian Networks (BN) allow the ship owners or other operators to visualize their mathematical knowledge and to discover possible relations between the variables, which influence the Port State Control (PSC) inspections (Yang, Yang & Yin, 2018).

The most contemporary research on the Bayesian Networks (BN) in relation to the Port State Control (PSC) inspections conducted by Dinis, Reixeria & Soares (2020). Researchers in their paper used the Bayesian Networks (BN) in order to develop a probabilistic approach for the Port State Control (PSC) inspections. This type of approach gave the researchers the opportunity to use the ships' risk profile variable as identified in Paris MoU. The main aim of Dinis, Reixeria & Soares (2020) approach is to allow the specialists to develop a static risk profile of the ships which navigate in a specific geographic area. In addition, the aim of Dinis, Reixeria & Soares (2020) approach is to identify the circumstance that the risk profile of the ships occurs. Finally, the researchers proposed this approach in order to identify the ships' risk profile after considering the

information generated by the automatic identification systems. The researchers collect their data from the Paris MoU digital platform and they used them in order to develop the Bayesian Network (BN), model. Additionally, the researchers used a quantitative methodology in order to assess the validity of their model. Researchers assessed their models by conducting a sensitivity analysis in order to predict its' validity.

4.4.1 BAYESIAN NETWORK (BN) AND GAME MODEL

Li & Tapiero (2010) and Yang, Yang & Yin (2018) proposed game models to improve the Port State Control (PSC) inspections. More specifically, Yang, Yang & Yin (2018) developed a game model based on the Bayesian Networks (BN). The researchers in their paper argued that the development of a game model needs three steps (confirming the participated players, figuring out the strategy of each player, and determining the payoff of each strategy).

Yang, Yang & Yin (2018) in their paper explain the game model risk-based approach. More specifically, they argue that hen the port authorities and the ship owner need to take a decision it is necessary to make their own choices based on the following parameter: the payoff of the selecting strategies under specific circumstances. One of the most important factors of the game model is the inspection risk why pay a key role in the Port State Control (PSC) inspections. The researchers in their attempting to quantify the parameter of the inspection risk, they combined the Bayesian Network (BN) with the game model. At this point, it is important to clarify that the game theory, in which the game model is based, is a theory that is widely used in the shipping industry. The combination of the Bayesian Network (BN) with the game model allowed the researchers to reflect accurately the conditions of the Port State Control (PSC) inspections after NIR have been implemented. The game theory allowed the researchers to propose a model by considering the performance risks factors that exists in the Port State Control (PSC) inspections. Their model is able to show the detention rates of the ships inspections under various conditions. This reveals the viability and the reliability of the model. During the game model development, the detention rate was considered as an important indicator that can predict the performance of a company. The game model managed to change the Port State Control (PSC) inspection regime as it depicts accurately the relationships developed between the ship owners and the port authorities. The main risk that a

ship needs to address when accepts inspection in port is the following: the detention if the ship is not confronted with the international regulation standards. This risk affects in a large degree the inspection estimates and the estimation of the detention model. Thus Yang, Yang & Yin (2018) considered this factor when constructing the game model. Therefore, the game model is considered a powerful risk assessment approach. This is because this model has the ability to estimate the detention rate in accordance with the inspection history.

4.4.2 PORT STATE CONTROL (PSC) Ship-Selecting Model Based on Improved Particle Swarm Optimization and BP Neural Network Algorithm

Yang et al. (2014) developed a new Port State Control (PSC) targeting model in order to improve particle swarm optimization. In order to develop their model, the researchers' considered the targeting mechanisms that have been proposed by the international MoUs and by the European Directive 2009/16/EC. The researchers managed to develop a reliable mathematical model that improve the algorithms of intelligent optimization. The algorithm that the researchers managed to develop, can offset the weak points of the neutral network. The results of the researchers shown that their Port State Control (PSC) model can improve the Port State Control (PSC) performance as concerning the speed and precision convergence.

5.FACTORS INFLUENCING THE PERFORMANCE OF THE PORT STATE CONTROL (PSC) INSPECTION

According to the current literature, the factors that could affect the Port State Control (PSC) inspection are the following: the ship generic factors (e.g., type of ship, model of ship, size of the ship, its performance and the manufacturer companies) and the ship inspections-based factors. The last years various researches (Knapp & Franses, 2007a, Knapp & Franses, 2007b, Knapp & Franses, 2007c, Knapp & Franses, 2008, Knapp & Franses, 2009, Payoyo, 1994, Fu et al., 2020, Yan & Wang, 2017, Tsou, 2019) have been published concerning the factors that influence the Port State Control (PSC) inspections. These factors are important because they reflect the international standards of ships' inspections. In addition, these factors are important because they are considered by the researchers who have developed the risk-based approaches for the improvement of the Port State Control (PSC) inspections.

The ship's inspection history is an important factor that influences the Port State Control (PSC) inspections. The factors that influence the determinants of detention during the Port State Control (PSC) inspections are the following: the ship's age, the ship's flag, the flag state as well as the classification society. For instance, Fan, Luo & Yin (2014) analyzed 18,000 inspections and they concluded that the ship's age is an important determinant factor that influences the performance of the Port State Control (PSC) inspections. The ship age has been characterized as an important determinant of the performance of the Port State Control (PSC) inspections by other researchers too (Knapp & Franses, 2007a, Knapp & Franses, 2007b, Knapp & Franses, 2007c, Knapp & Franses, 2008, Knapp & Franses, 2009, Payoyo, 1994, Fu et al., 2020, Yan & Wang, 2017, Tsou, 2019).

Indicatively, it is worth saying that Tsou (2019) argued that most of the individuals keep a close eye on generic factors which include the age of ship, its type and its' flag. These characteristics are predictors of the deficiencies of the ship by using the models of Poisson constructed from 4,080 observations. It was further analyzed that the effort of Port State Control (PSC) inspection was based on ship age at around 40%, ship manufacturing organization 31%, and the area of inspection 17% which were accumulated from 26,515 inspections. With the help of big data processes, it was

measured that the ships having an age of more than 25 years and cargo of less than 8,500 gross tonnages purpose type are needed to be inspected and at some flags can bring worse outcome in the Port State Control (PSC) inspections (Tsou, 2019).

Cariou et al. (2008, 2007) after analyzed 4080 ships' inspections concluded that the ship and the ships' type and flag state are important factors that determine the effectiveness of Port State Control (PSC) inspections. The same research results have been generated by other researchers too (Cariou & Mejia, 2008, Jin et al., 2019, Quinlan, 2014, Du & Feng, 2018, Smith, 2018).

For example, Cariou et al. (2008) after analyzing 26,515 ships inspections of the Indian Ocean MoU during the period 2002-2006 concluded that the most influential factors of the Port State Control (PSC) inspections are both the ship age and the ship flag. Jin et al., 2019 found other important factors, that determined the Port State Control (PSC) inspections except from the ship flag and the ship age. These factors are the classification society and the flag state as well as the vessel history. Quinlan (2014) found that ship age, gross tonnage, flag state as well as the classification society are the most prevailing factors in the international shipping industry that determine the effectiveness of the Port State Control (PSC) inspections. Fan et al. (2010) found that the ship age is the most important factor that determines the effectiveness of the Port State Control (PSC) inspections. Thus, most of the researchers propose that the Port State Control (PSC) inspections can be improved when the historical data of the ships are going to be incorporated into the target systems. Hei et al. (2019) identified some other important factors that can determine the effectiveness and the performance of the Port State Control (PSC) inspections. These factors are the ship arrivals inspections and the causality databases.

Referring to the non-ship attributes, Knapp & Franses (2006) with the help of econometric methodologies measured the factors with the most influence, they demanded a logistic model that relied on 18,313 inspections worldwide to extract the changes in ways of detention and recognized the deficiencies. The above describes methodologies use models based on (count data model, regression model, and variance decomposition analysis) to implement to case sets of data and measure the factors with the most determination on Port State Control (PSC) inspection results. The final outcome shows that the inspection results with being impacted by both the factors which include the factors related directly to ship and Port State Control (PSC) inspection.

The procedure to inspect the ship in the Port State Control (PSC) inspection is a major issue. It is not possible to inspect all the ships docking in the port due to shortage of time, human and budget

resources but if the standard of the procedure is not implemented and the flaws are not identified and the deficiencies are not fulfilled, it could possess a noticeable threat to the maritime environment. A good area of literature has entirely focused on the selection of ship scheme to undergo the process of selection with more efficiency. A new method of ship assessment based on giving each docking ship a score that will be calculated on its age, insurers, flag, classifications, and operators.

At this point, it is important to make a quick reference to the effect of the Port State Control (PSC) inspection. As the state of flag is considered as the first observation to look for in case of defense in the extraction of substandard ships, the second line is considered to be a port state. After the introduction of the first Port State Control (PSC) program, a huge volume of assessment has talked about the changes in it.

Basically, the changes of Port State Control (PSC) inspection are based on three measures which include the effect brought over maritime safety, change on the inspected ships, and on the protection of the environment.

Methodology:

- Risk analysis:

  To estimate the level and chances of risk from basic activity

- Risk assessment:

  An acceptability that will be based on comparison with standard risk and after trial of different risk reducing steps

- Risk management:

  The steps in which different risk reduction measures are selected and also their implementation on the overall process.

There are wide range of methods in risk assessment:

• Hazard identification tools

Judgement

FMEA – Failure Modes and Effects Analysis

SWIFT – Structured What-If Checklist Technique

HAZOP – Hazard and Operability Study

• Risk Assessment techniques

Qualitative (risk matrix)

Quantitative risk assessment (coarse and detailed levels)

Hazard identification:

Any condition that has this potential to harm or damage the safety of humanity, environment, property or any business is termed as Hazard. Like shuttle tanker can be categorized as hazard because it can collide with production installation

HAZID (hazard identification) is the process of identifying the hazards. Using the risk assessment techniques in order to obtain the total list of all hazards this is also known as "failure case selection". Significance of all hazards are obtained and evaluated then different measures are established in order to reduce the risk from them and this is known as "hazard assessment".

5.1HAZARD CHECKLIST

This is a full range of written list of questions that include full range of safety issues. They are used in order to check a design and to confirm that everything is on place. For offshore activities a list of checklists is developed by American Petroleum Institute which actually address the risk of drilling API 14C, 14E, 14F, 14G, 14J, and checklist on safety and environment management API RP75. These are the 14 checklists that are very detailed and styled. There are some other types of checklists too that are widely use in risk management. Hazard categories are included in general form of checklist. Some checklist has their focus mainly to assist the risk assessment than to check the design. These kinds of checklists can be made from the history of previous checklist. And can help- in making an effective mean of generating perfect checklist with standard hazards suitable for HAZID. Following table is giving an example of general checklist. This is useful for general offshore inspection and it can be considered incomplete for unusual installation.

Table 1: Example of generic hazard checklist (CMPT 1999)

Blowouts
- Blowout in drilling
- Blowout in completion
- Blowout in production (including wirelining etc)
- Blowout during workover
- Blowout during abandonment
- Underground blowout

Also covered under blowouts are:
- Well control incidents (less severe than blowouts)
- Fires in drilling system (e.g. mud pits, shale shaker etc)

Riser/pipeline leaks - leaks of gas and/or oil from:
- Import flow-lines
- Export risers
- Sub-sea pipelines
- Sub-sea wellhead manifolds

Process leaks - leaks of gas and/or oil from:
- Wellhead equipment
- Separators and other process equipment
- Compressors and other gas treatment equipment
- Process pipes, flanges, valves, pumps etc
- Topsides flowlines
- Pig launchers/receivers
- Flare/vent system
- Storage tanks
- Loading/unloading system
- Turret swivel system

Non-process fires
- Fuel gas fires
- Electrical fires
- Accommodation fires
- Methanol/diesel/aviation fuel fires
- Generator/turbine fires
- Heating system fires
- Machinery fires
- Workshop fires

Non-process spills
- Chemical spills
- Methanol/diesel/aviation fuel spills
- Bottled gas leaks
- Radioactive material releases
- Accidental explosive detonation

Marine collisions - impacts from:
- Supply vessels
- Stand-by vessels
- Other support vessels (diving vessels, barges etc)
- Passing merchant vessels
- Fishing vessels
- Naval vessels (including submarines)
- Flotel
- Drilling rig

Continued…

- Drilling support vessel (jack-up or barge)
- Offshore loading tankers
- Drifting offshore vessels (semi-subs, barges, storage vessels)
- Icebergs

For each vessel category, different speeds of events, such as powered and drifting may be separated.

Structural events
- Structural failure due to fatigue, design error, subsidence etc
- Extreme weather
- Earthquakes
- Foundation failure (including punch-through)
- Bridge collapse
- Derrick collapse
- Crane collapse
- Mast collapse
- Disintegration of rotating equipment

Marine events
- Anchor loss/dragging (including winch failure)
- Capsize (due to ballast error or extreme weather)
- Incorrect weight distribution (due to ballast or cargo shift)
- Icing
- Collision in transit
- Grounding in transit
- Lost tow in transit

Dropped objects - objects dropped during:
- Construction
- Crane operations
- Cargo transfer
- Drilling
- Rigging-up derricks

Transport accidents - involving crew-change or in-field transfers
- Helicopter crash into sea/platform/ashore
- Fire during helicopter refuelling
- Aircraft crash on platform (inc military)
- Capsize of crew boats during transfer
- Personal accident during transfer to boat
- Crash of fixed-wing aircraft during staged transfer offshore
- Road traffic accident during mobilisation

Personal (or occupational) accidents

Construction accidents - accidents occurring during:
- Construction onshore
- Marine installation
- Construction offshore
- Hook-up & commissioning
- Pipe laying

Attendant vessel accidents

Diving accidents

Source: Quilan (2014)

Table 2: Example of keyword checklist

Key Word used in HAZID	Example of Hazard
Direct fire	Ignited blow-out Ignited process fire Fire in paint store
Loss of breathable atmosphere	Smoke ingress from HVAC Asphyxiation
Direct toxic	Toxic gas release
Explosion overpressure	Explosion from process gas leak
Dropped objects	Dropped load from crane Swinging load hit to process
Vehicle collision	Helicopter crash Ship collision to legs
Structural collapse	Crane collapse Leg failure in design load Extreme weather
Mechanical failure	Gas turbine rotor blade failure
Electrocution	Occupation accident
Pressure/loss of containment	Air receiver failure Unignited process vessel failure
Water/drowning	Deluge in process Man overboard
Direct chemical	Drilling chemical leak Lab chemical exposure
Occupational accidents	Trips, falls
Hydrocarbon leak general	Diesel tank failure Process leak

Source: Ambion (1997)

The strengths of hazard check list are the following:

- It helps to reduce the accidents.
- It uses the experience from past risk management approaches.
- It can be made through a single analyst even at less expenses.
- It helps in comparison between HAZIDS and to make standard hazard category.
- It does not require very much information about installation and thus perfect for concept design.

The weaknesses are the following:

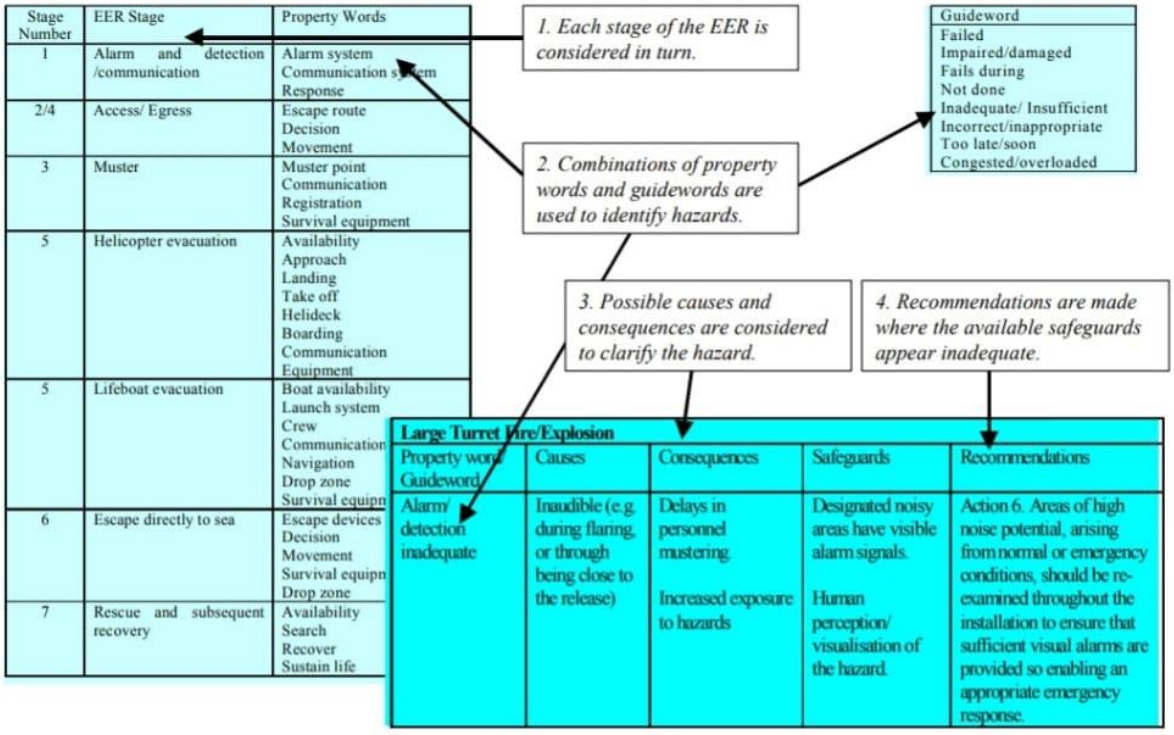
- It is all limited to past experiences and accidents.
- It does not promote brainstorming level of thinking.
- Give less angle toward nature of hazards.

5.2 HAZOP

A method of measuring and extracting hazards which are capable of affecting the safety and operability relied on the usage of guidewords are known as hazard and operability (HAZOP). A set of experts in multiple directions of the installation, under the influence of an independent HAZOP leader, systematically takes every sub-system of the method in turn, typically pointing to undergo the process and diagrams of instrumentation (P&IDs). They acquire help from the standard list of guidewords to point them to rectify deviations from design intent. For every credible deviation, they take measurable causes and the situation it can occur, and even if more precaution should be advised. they keep their conclusion on a record in format of standard during the sessions.

Although they point to industries who process onshore, process equipment of HAZOP of offshore is more or less importantly the same. HAZOP stands at one of the most widely used HAZID implementations in the offshore industry. However, its classic form is planned for process which involves continuous chemical as expressed in P & IDs and its considered not so efficient for marine hazards. The HAZOP technique can be updated to implement to hazards of non-process, but there is measure of damage that changes applied to the guidewords will extract outcome of some hazards being ignored. Hence standard changes are considered to ad-hoc variations.

Fig 4: Example of EER HAZOP



Source: Boyle & Smith (2000)

5.3FMECA

A systematic methodology of extracting the points of failures modes of a system based on electrical and mechanical is known as failure modes, effects and critically analysis (FMECA) and its simple form is FMEA. Mostly, one or two analytics focus each component in turn, selectively measured the effects and its criticality of a presence of failure. The study uses a form that starts with a technical list of all the major parts in the system, and typically involves:

- Reason of failure
- Name of Component
- Modes of possible failure

- The process of detecting a failure
- Implications of failure over primary system function
- The implications on other components
- Necessary action require to preventative/repair

Failures are stated as important if the frequency or severity index is high. In these scenarios, a special protection measure protocol is implemented.

Fig 5: Example for FMEA Work sheet

Filling ballast tanks under gravity							
Ref.	**System /Equip. Failure**	**Cause**	**Effect**	**Detection**	**Mitigation-Compensation-System Response-Safeguards**	**Overall assessment**	**Overall criticality**
1BF	Sea Chest	1. Blocked	Tanks do not fill. Reduced stability, change of heel/trim increased hull stresses	* Valve position indicators. * Ballast tank level radar/sounding system. * If severe, angle of heel/trim.	i) Clean chest with steam. ii) Redundancy 3 other sea chests	In a worst case where failure was not acted upon quickly then a degraded state could arise where the ballasting operation of several tanks could be affected	D
1BF	Sea Chest	2. Loss of sea chest grid integrity.	Ingress of foreign bodies possible blockage of control valves and suction piping. Tanks do not fill. Build up of debris in system. Reduced stability, change of heel/trim increased hull stresses	* Valve position indicators. * Ballast tank level radar/sounding system. * If severe, angle of heel/trim.	i) Clean chest with steam. ii) Redundancy 3 other sea chests	In a worst case where failure was not acted upon quickly then a degraded state could arise where the ballasting operation of several tanks could be affected	D
2BF	Sea Chest	1. Partial Blockage	Reduced filling rate.	* Valve position indicator. * Ballast tank level radar/sounding system.	i) Clean chest with steam ii) Redundancy 3 other sea chests	Overall effect considered incipient due to detection ability and redundancy	I
3BF	Sea Chest	1. Leak at sea chest	Loss of ballast control in affected tank. Change of heel/trim	* Valve position indicator. * Ballast tank level radar/sounding system.	i) Continuously pumped to maintain correct level. ii) Isolate with sea chest blanks. iii) Equalises to exterior sea height in affected tank.	Loss of control in a tank is considered as degraded	D

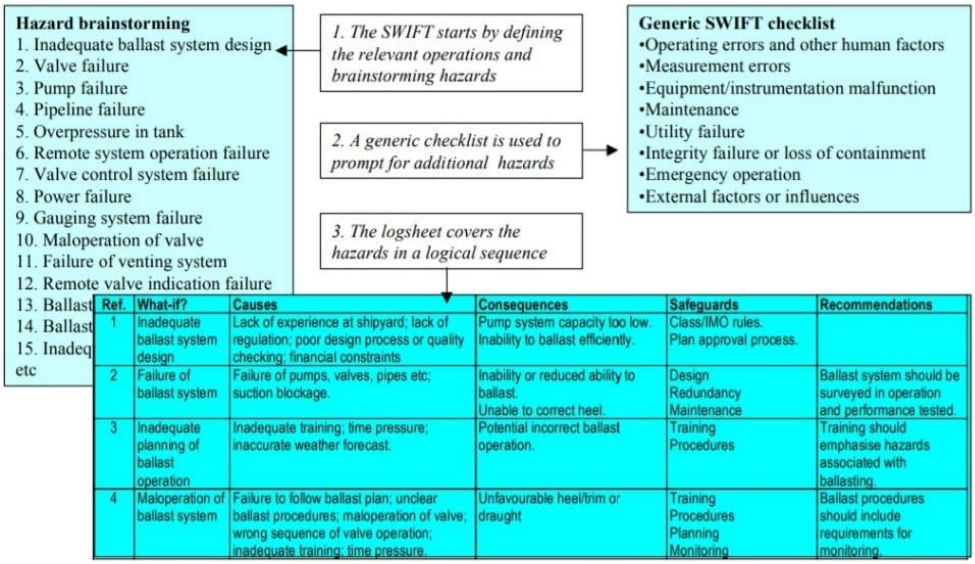
Source: Boyle & Smith (2000)

5.4 SWIFT

The methodology of what-if marking (SWIFT) technique is a process of analyzing and extracting hazards with help of brainstorming. SWIFT is a far more well-organized form of "What-if analysis" but is considered as a rigorous of low level and faster alternate to HAZOP. Comparing with HAZOP, SWIFT works on a team which has knowledge of the installation, under the influence of a technical in the SWIFT technique. The main change compared to a HAZOP are:

- The conversation moves forward systematically through the installation of the modules or operations performed at the level of systems and literature, instead of individual items or tasks.
- The method is totally dependent on brainstorming and checklists to point out the hazards, in place of a formal list of guidewords. The conversation may start with the words "What if", and other vocabulary for starting the argumentative approach might be "How could". It might be suitable to put out all the questions in a manner of brainstorming before working to extract the answer out of them.

Fig 6: Example of SWIFT of Ballast System



Ref.	What-if?	Causes	Consequences	Safeguards	Recommendations
1	Inadequate ballast system design	Lack of experience at shipyard; lack of regulation; poor design process or quality checking; financial constraints	Pump system capacity too low. Inability to ballast efficiently.	Class/IMO rules. Plan approval process.	
2	Failure of ballast system	Failure of pumps, valves, pipes etc; suction blockage.	Inability or reduced ability to ballast. Unable to correct heel.	Design Redundancy Maintenance	Ballast system should be surveyed in operation and performance tested.
3	Inadequate planning of ballast operation	Inadequate training; time pressure; inaccurate weather forecast.	Potential incorrect ballast operation.	Training Procedures	Training should emphasise hazards associated with ballasting.
4	Maloperation of ballast system	Failure to follow ballast plan; unclear ballast procedures; maloperation of valve; wrong sequence of valve operation; inadequate training; time pressure.	Unfavourable heel/trim or draught	Training Procedures Planning Monitoring	Ballast procedures should include requirements for monitoring.

Source: Boyle & Smith (2000)

6.QUANTITATIVE METHODS

6.1 APPLICABILITY

Quantitative risk analysis considered as one of the complicated techniques for hazards evaluation but make sure this technique must be where it is properly needed and gives fruitful consequences. UKOOA [1999] studied clearly and proposes that this QRA is actually one of the adequate way for determination of Type B basically which also associated with the risk trade-offs, divergence from quality of performance or any other meaningful economic information. EXCEPT from all these settlements, QRA provides us with unlimited store of information which make us capable of choosing right decisions and also an adequate method to opposite to other resources of research departments like engineering perception and for company proposes QRA plays an important role as main instrument of engineering research which have some sympathetic role in regarding to awareness.

Awareness in sense of patterning the tragedies which also included their action as shield in accurate manners, it leads all the supposition to the clear end and for this reason comes up a good way of handling the state of tentativeness than any other researches that are relied on judgment. The safety case order of working clearly depends upon QRA technique to demonstrate temporary protection and means of deportation which may indulge in many problems like fire and smoke ALARP but these all cannot be apply for marine environments. There is also quite many reasonable function of QRA technique as it can be seen playing role for ship-platform collision risks and it is verified with great influences for organizing purposes. There are chances this procedure can be used for marine hazards but for this it is not highly appreciated than the above discussed role of QRA for fire including activities and for any other eruption matter.

Frequencies and Consequences:

QRA actually balances wide differences between two significant unit of risk.

The affluence of event for example their survival in specific.

The results of event including factors such as mortality rate any harm or the any poisons effect. Role hydrocarbon leakage in these destruction causing activities considered more often. And the idea of hydrocarbons role can be seen clearly with influence in way of eruption causing manners which has direct effect on human beings, materials and all-around universe. However, this leak of hydrocarbon gives the idea that frequencies can be more often have no any dependence. Here also studied description for the marine life. This complex environment of nature invited researchers for its vast consideration. Methods of analysis and results given below.

6.2 FAILURE AND CAUSES

Failure causes are considered worthy in estimation of any particular threat also their aftermath can relate to the reality for some extent. For instance, a horrible risk like 'ballast system failure' possibly depicted below by two failure cases

1. accidental ballasting of one compartment.
2. accidental ballasting of two compartments.

Furthermore, QRA technique has to play its role in regarding of these two events improperly.

Frequency methods:

The analysis in frequency methods involve the evaluation of risks of happening of each failure case. Main steps in order to estimate the frequencies are;

Historical accident frequency data

This require the previous knowledge of the accidents. This one is simple approach and easy to get absorb but this is only useful in already present technology with much experience of accidents and where the particular records were present.

Fault tree analysis

This actually related to breaking down of some incident into its component causes. Which also include human error and evaluating the frequency of every component from comparison with generic data of history.

Simulation

Simulation models can be used in order to get frequencies of some types of incidents. Like in a ship collision where time domain simulation and analytical computation can help to estimate the frequencies of collision from the range of movement of ship in that particular area.

Event tree analysis

This is actually a path of showing how the incident happen from an initiating event in form of branches with rise to few possible results or outcome too.

Human reliability analysis

This include estimation of human error to accident and it can also generate through the inputs of fault tree analysis or event tree analysis

Judgmental evaluation

Based on judgment of some experience it is easy to select a frequency. This is a simple assessment for like some frequent events for the events which have some minimum risks

Bayesian analysis

This is kind of systematic type of combining the past data with the judgment and uncertainty measures. It is very rare in use.

7. RESULTS AND CRITICAL EVALUATION

7.1 RISK-BASED APPROACHES

The aim of this chapter is to present and comment the research results of the in-depth literature review. Figure 7 shows the number of papers that have been published for each of the Port State Control (PSC) risk-based methods. Therefore, Figure 7 shows which of the risk-based method is most popular in the international literature. Accordingly, Figure 8 shows the evolution of the literature on the Port State Control PSC) risk-based approaches over the time.

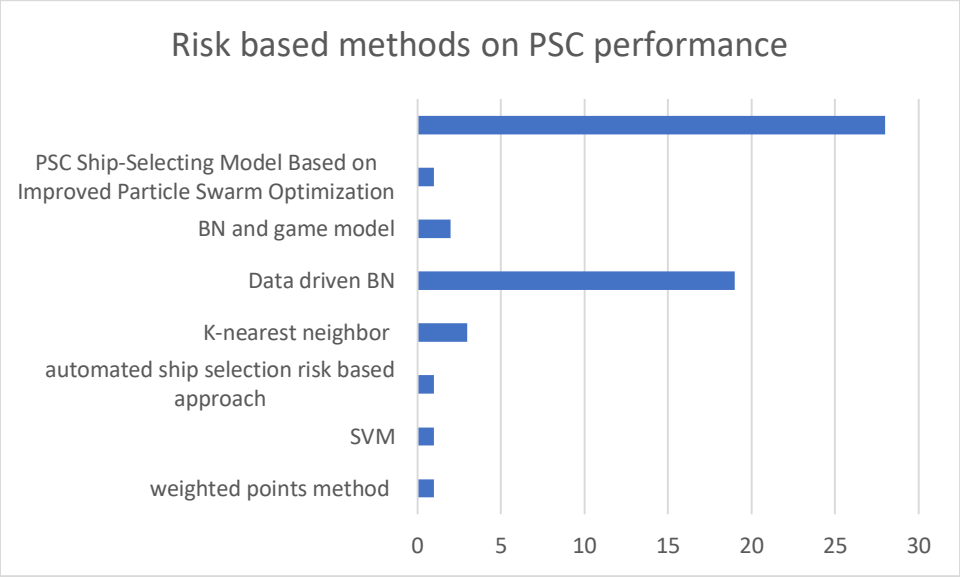
As it is contemplated in Figure 7 most of the selected papers focus on the data driven BN. Fewer studies have been published on other approach such as on the Support Vector Machine (SVM) method, the Bayesian (BN) and game mode and the K-nearest neighbor.

The researchers consider the approach of the data-driven Bayesian Networks (BN) as being innovative. The researchers used this method in order to analyze the risk factors, which are relevant to the Port State Control (PSC) and thus can influence it, by predicting the probability of vessel detention. The data-driven Bayesian Network (BN) is a successful model, that have been tested several times and in several cases. This model gives the researchers the opportunity to use the expert knowledge and to make predictions by integrating such knowledge in the model. Most of the researchers that use the data-driven Bayesian Networks (BN) agree that this is a causal probabilistic model adequate to make accurate predictions. But the basic limitation of this model is that is dependent on the historical data and sometimes such data is difficult to be collected.

At this point it is important to clarify that Bayesian Networks (BN)are widely used in different sectors of economy due to the opportunities that they offer to the specialists and the researchers. For example, Bayesian Networks (BN) can take information about an event that have been occurred during the past and make future predictions. A strong point of the Bayesian Networks (BN)is that they are acyclic graphs with nodes that represent specific variables.

The effectiveness of the Bayesian Networks (BN)can explain why some researchers used them in combination with the game model. Since their introduction to the international literature Bayesian Networks (BN)have been used by two researchers in combination with the game model.

Figure 7 The number of papers that have been published for the risk-based methods.



Source: Figure created by the author based on excel data

Table 3 presents the researches on the risk-based approaches, that detected during the in-depth literature review.

Table 3: The researches on the risk-based approaches that detected during the in-depth literature review

Research on risk-based approaches	Researches
K-nearest neighbor	(Kesavaraj, 2013, Gao et al., 2008, Shen et al., 2003).
Support Vector Machine method (SVM)	(Xu et al., 2007).
Data driven Bayesian Networks (BN)	(Hänninen & Kujala, 2012; Goerlandt & Montewka, 2015; Zhang et al., 2015, Banda, O.A.V. et al., 2016; Zhang et al., 2013; Hänninen et al., 2014; Wu et al., 2015, Lehikoinen et al., 2013, Banda et al., 2016; Zhang et al., 2013; Hänninen et al., 2014; Wu et al., 2015, Montewka et al., 2017, Montewka et al., 2014A, Yang et al., 2018, Lin et al., 2014, Min et al., 2011, Wisse et al., 2008, Vinnem et al., 2012, Cain 2001, Wisse et al. 2008, Dinis, Reixaria & Soares, 2020).
Bayesian Networks (BN) and game model	(Li & Tapiero, 2010, Yang, Yang & Yin,2018).
Automated ship selection risk-based approach	(Shen, 2003).
Weighted point method	(Kara, 2016).
Port State Control (PSC) ship selected model based on improved Particle Swarm Optimazation	(Yang et al., 2014)

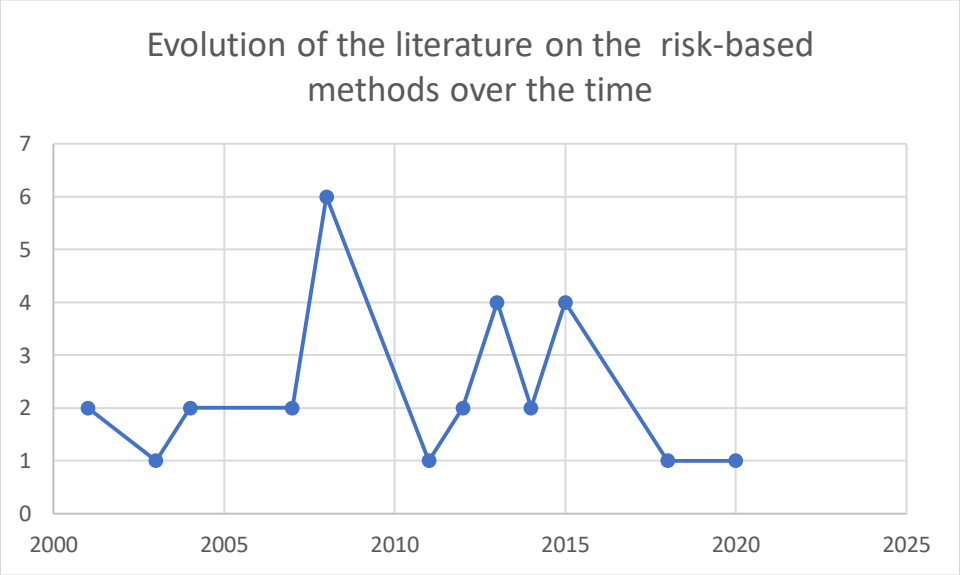
Source: Table created by the author based on the in-depth literature review

The first studies on Port State Control (PSC) performance based on a risk-based approach published in 2003 and in 2004. More specifically, Shen (2003) and Yang (2004) proposed a risk-based approach to assess the risk of Port State Control (PSC) systems. The basic disadvantage of the risk-based approached provided by Shen (2003), Yang (2004) and Kara (2016) is the subjectivity of the expert judgments. This subjectivity may influence the results. Thus, Xu et al. (2007) introduced the Support Vector Machine (SVM) risk-based approach.

As figure 6 shows the most studies on the risk-based approaches have been published during 2008, 2013 and 2015. The New Inspection regime that established in 2011 by Paris MoU can explain the increased research interest of the improvement of the Port State Control (PSC) inspections during the years 2012, 2013 and 2015. Indicatively, it can be referred that during 2012 two studies were identifies and in 2013 and 2015 four studies were identified.

The research interest on the improvement of Port State Control (PSC) inspections is also increased during 2008 (6 studies identifies). This research interest can be explained if we consider that in 2007 the states under the Paris MoU joining a program with the aim to make investigations on how the Port State Control (PSC) can be improved based on operational, technical and administrative procedures. In addition, the research interest can be explained if we consider that in 2007 under the Paris MoU took place approximately 5427 inspections on 5120 ships. The results of the inspections were not encouraging as many ships had deficiencies (Paris MoU, 2007). Therefore, the researchers during 2008 period attempted to find ways to improve the Port State Control (PSC) performance based on risk-based approaches. It is worth to say that during the period of 2008 the prevailing Port State Control (PSC) risk-based approach is the BN.

Figure 7 Evolution of the literature on the risk-based approaches over the time

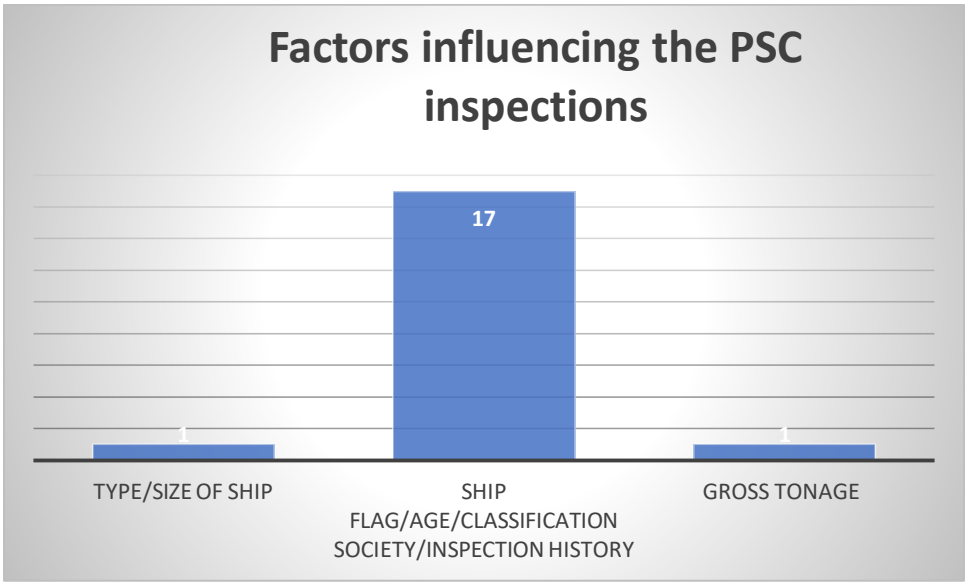


Source: Figure created by the author based on excel data

7.2 FACTORS INFLUENCING THE PERFORMANCE OF THE PORT-STATE CONTROL (PSC) INSPECTIONS

Figure eight shows the interest of the international researchers on the factors that influence the Port State Control (PSC) inspections. More specifically, this figure shows how many researches have been published on factors influencing the Port State Control (PSC) inspections through the years.

Figure 8 Factors influencing PORT STATE CONTROL (PSC) inspections



Source: Figure created by the author based on excel data

Table 4 presents the researches published on factors that influence the performance of the Port State Control (PSC) inspections.

Table 4: The researches published on factors that influence the performance of the Port State Control (PSC) inspections.

Factors influence the performance of the Port State Control **(PSC) inspections**	**Researchers**
	(Knapp & Franses, 2007a, Knapp & Franses, 2007b, Knapp & Franses, 2007c, Knapp & Franses, 2008, Knapp & Franses, 2009, Payoyo, 1994, Fu et al., 2020, Yan & Wang, 2017, Tsou, 2019, Fan, Luo & Yin, 2014, Cariou et al., 2008, 2007, Mejia, 2008, Jin et al., 2019, Quinlan, 2014, Du & Feng, 2018, Smith, 2018, Chi & Zun, 2010, Ravira & Piniela, 2016).

Source: Table created by the author based on the in-depth literature review

Based on figure 8, it can be concluded that 17 out 19 researches, which examined in this paper, focus on the following factors: the ship age, the ship flag, the inspection history and the classification society. Indicatively, some researches that revealed the importance of the aforementioned factors are the following (Knapp & Franses, 2007a, Knapp & Franses, 2007b, Knapp & Franses, 2007c, Knapp & Franses, 2008, Knapp & Franses, 2009, Payoyo, 1994, Fu et al., 2020, Yan & Wang, 2017, Tsou, 2019).

The aforementioned factors are considered by the researchers in order to develop the Port State Control (PSC) risk-based approaches. More specifically, in most of the risk-based approaches examined in this Dissertation the inspection history is the most prevailing factor that is being considered during the construction of the models. In addition, it is worth to say, that in Bayesian Networks (BN) approach, which is the prevailing risk-based approach, the ship age and the ship type are among the basic factors that are being considered. For instance, the ship age can predict the negative environmental consequences that a damaged ship can provoke.

8.CONCLUSIONS

The aim of this Dissertation was to identify the risk-based approaches, that are proposed in the international literature, for the improvement of the Port State Control (PSC) performance. In addition, this research aimed to identify the factors that influence the Port State Control (PSC) inspections based on international literature. To achieve the aim of the Dissertation an in-depth literature review was selected as a research methodology. The sample of this literature review was 47 academic articles which have been published in high-quality journals. A total of 28 papers identified which proposed risk-based approaches for the improvement of the Port State Control (PSC) inspections' performance. Additionally, a total of 19 papers were identified which examined the factors that influence the Port State Control (PSC) performance.

Port State Control is a matter of considerable importance for the shipping industry as the damages that can be caused in the global coastlines by the ships have important environmental, economic, and social consequences. An example of the devasting damages, that a ship can cause, is the Torrey Canyon. Torrey Canyon shocked the global public opinion and the world governments as it released 100,000 tons of oil into the sea. Thus, very early, in 1948 the governments decided to sign the International Convention on Safety of Life at Sea. In addition, globally exist many MoUs which aim to eliminate the negative impacts of shipping accidents.

In this context, Port State Control (PSC) is a matter, that has attracted the researchers' interest since 2003. Since then researchers have proposed risk-based approaches for the improvement of the Port State Control (PSC) inspections. The analysis of the Dissertation's research results, shown that most studies on the risk-based approaches have been published during 2008, 2013, and 2015. In addition, the analysis showed that the Bayesian Networks (BN) (Hänninen & Kujala, 2012; Goerlandt & Montewka, 2015; Zhang et al., 2015, Banda, O.A.V. et al., 2016; Zhang et al., 2013; Hänninen et al., 2014; Wu et al., 2015, Lehikoinen et al., 2013) is the most proposed risk-based approach for the improvement of the Port State Control (PSC) inspections. Fewer studies have been published on the K-nearest neighbor risk-based approach and only one study has been published on the Support Vector Machine (SVM) risk-based approach.

The most contemporary research on the Bayesian Networks (BN) in relation to the Port State Control (PSC) inspections conducted by Dinis, Reixeria & Soares (2020). In the international literature were not conducted other contemporary researches on the Bayesian Networks (BN) during the period 2018-2020. Nevertheless, studies on Bayesian Networks (BN) have been

published during 2013-2016. At this point, it is important to highlight that Dinis, Reixeria & Soares (2020) model to Bayesian Networks (BN) is reliable and valid as the researchers conducted a sensitivity analysis in order to develop their mathematical model.

The risk's analysis shift from accident investigation to factors that influenced the Port State Control (PSC) inspections begun during 2006. The research interest of the Bayesian Networks (BN) can be attributed to a wide variety of the benefits that they offer to the shipping inspections. For instance, Bayesian Networks (BN) use graphical representations of the variables and are based on mathematical models. This fact increases their validity and reliability. In addition, it is important to highlight, that due to their advantages BN, have been used to cover a wide variety of issues in the shipping industry such as the ship-ship collision, maritime accident and analysis and others. The fact that Bayesian Networks (BN)since their introduction have been used to give solutions in many shipping threats means that the researchers acknowledge their prospects and dynamics. Bayesian Networks (BN) does not come without limitations. The most important limitation of these models is that they require much data in order to be developed. Sometimes these data are historical and thus it is difficult to be obtained. In addition, Bayesian Networks (BN) are considered as being very complex as their data table is increasing rapidly when new parents' nodes are added to the network. It is worth to say that Li et al. (2014) to offer some solutions to the limitation of Bayesian Networks (BN) by developing a logit model and binary logistic regression but this model is also complex as it requires a large amount of data.

Except for the investigation of the risk-based approaches, that can improve the Port State Control (PSC) performance, this Dissertation also studied the factors that influence the Port State Control (PSC) inspections. Seventeen out 19 researches (Knapp & Franses, 2007a, Knapp & Franses, 2007b, Knapp & Franses, 2007c, Knapp & Franses, 2008, Knapp & Franses, 2009, Payoyo, 1994, Fu et al., 2020, Yan & Wang, 2017, Tsou, 2019), which examined in this paper, focus on the following factors: the ship age, the ship flag, the inspection history, and the classification society. All these factors have been examined by the researchers who used many case studies. It is important to refer that the aforementioned factors, which detected in the literature review, are called "generic factors" in Paris MoU. The importance of these factors highlighted in the Dissertation as these factors are used by the risk-based approaches. For example, Bayesian Networks (BN) use the ship age, the ship flag, and the inspection history in order to improve their predictions. An important limitation, that it was detected during the analysis of factors, was that

only a few studies have been published which examine the non-ship factors that influence the Port State Control (PSC) inspections. During the in-depth literature review, only one research detected which examined the non-ship factors that influence the performance of Port State Control (PSC) inspections. This research was conducted by Knapp & Franses (2006). The positive point is that this research is very reliable and valid as it used an econometric methodology to reach safe conclusions. But, in the international literature, there is still space for improvement concerning the non-ship factors that influence the Port State Control (PSC) inspections.

Upon the completion of the Dissertation revealed the importance of the risk-based approaches for the improvement of the Port State Control (PSC) performance. In addition, the Dissertation revealed the factors that influence the Port State Control (PSC) inspections. This Dissertation contributed to the international literature by summarizing the existing theoretical knowledge on the Port State Control (PSC) inspections and specifically on the risk based-approaches used to improve the Port State Control (PSC) inspections. The in-depth literature reviews are always important to every scientific field due to their advantages. For example, one of the major advantages of this research is that it used a rigorous method in order to identify, analyze and explain the research results on the risk-based approaches and on the factors influence the performance of the Port State Control (PSC) inspections.

FUTURE RESEARCH OPPORTUNITIES

Upon the completion of the Dissertation some recommendations on future research opportunities are proposed. Firstly, it is proposed that the future researches should focus on the improvement of the Bayesian Networks (BN) risk-based approach. In addition, the future research should focus on the harmonization of the Paris MoU database with the Bayesian Networks (BN) approach. Furthermore, it is suggested that more contemporary researches should be published on Bayesian Networks (BN) risk-based approach in different European counties. Last but not least, it is suggested that more researches should be published that combine the Bayesian Networks (BN) with the game model theory. This theory is widely adopted in the transportation industry and thus it should be interesting and useful if more researches were published on this field. Up to the moment, based on the international literature the regime of the Port State Control (PSC) inspections is effective but there is still room for improvement. The combination of the databases

of the worldwide MoUs for the development of new risk-based approaches is also suggested. Such a combination will contribute to the harmonization of the global standards on the Port State Control (PSC) inspections. Lastly, it is proposed that more researches should be conducted on the non-ship factors that influence the performance of the Port State Control (PSC) inspections. The in-depth literature review identified only one study that focus on this research area.

LIMITATIONS

Every scientific effort has its' limitations. The basic limitation of this research is that only one database was used in order to select the journal articles. This means that this research is limited as concerning its' research scope. Thus, more researches should be published with the same methodology. But the future researches should select a wide range of databases in order to ensure their objectivity. In addition, another limitation of this research is the researcher's subjectivity during the interpretation of the data. This is a limitation, that exists in every in-depth literature review.

References

Ambion (1997) '*Approaches to Hazard Identification'*, Ambion Consultants, Offshore Technology Report OTO 97 068, Health & Safety Executive, HSE Book.

Banda, O. A. V. (2016) 'Risk management model of winter navigation operations', *Marine Pollution Bulletin*, **108**(1), pp. 242-262.

Bell, D. (1993) 'Port State Control vs flag state control: UK government position', *Marine Policy* **17** (5), pp. 367–370.

Bryman, A. (2017) 'Quantitative and qualitative research: further reflections on their integration', *Mixing methods: Qualitative and quantitative research*, **1** (2), pp. 57-78.

Bijwaard, S. and Knapp, S. (2009) 'Analysis of ship life cycles—The impact of economic cycles and ship inspections', *Marine Policy* **33** (9), pp. 350-369.

Bello, G. B. (1994) 'Maritime Developments in Nigeria: Problems and Prospects-A case study of National Maritime Authority'. *HND Project.* Yaba, Lagos, Nigeria: College of Science and Technology.

Boyle, P. & Smith, E.J. (2000) 'Emergency Planning using the HSE's Evacuation, Escape and Rescue (EER) HAZOP Technique, *Hazards XV, Symposium Series*, 147, Institution of Chemical Engineers, Rugby.

Bloor, R. Datta, Y. Gilinskiy, T. Horlick-Jones (2006) ;Unicorn among the Cedars: On the Possibility of Effective 'Smart Regulation' of the Globalized Shipping Industry', *Social & Legal Studies* **15(**4), pp. 534-551.

Cain, C. F., Birmingham, R. W., Sen, P. and Cripps, R. M. (1999) 'A practical formal safety assessment system for the marine design environment', *Marine Technology*, **36** (4), pp. 183-193.

Cariou, P., Mejia Q.M. and Wolff, F-C. (2001) 'An econometric analysis of deficiencies noted in Port State Control inspection', *Maritime Policy and Management*, **45**(1), pp. 124-130. P.

Cariou, M.Q. Mejia Jr., F.C. Wolff (2008) 'On the effectiveness of Port State Control inspections, Transport', *Res. E Logist. Transport. Rev.* **44** (3), pp. 491–503, https://doi.org/10.1016/j.tre.2006.11.005.

Cariou, P. and Wolff, F. C. (2011) 'Do Port State Control inspections influence flag-and class-hopping phenomena in shipping'? *Journal of Transport Economics and Policy,* **45**(2), pp. 155-177.

Chi, G. and Jun, S. (2010) 'Automatically optimized and self-evolutional ship targeting system for Port State Control', *Systems Man and Cybernetics (SMC). IEEE International Conference on 2010*, IEEE, pp. 791–795

Clarke, A. (1994) 'Port State Control or sub-standard ships: who is to blame? What is the cure?' *Lloyd's Maritime and Commercial Law Quarterly* **2** (1), pp. 202–209.

Cuttler, M. (1995) 'Incentives for reducing oil pollution from ships: the case for enhanced Port State Control', *Georgetown International Environmental Law Review* **8** (1), pp. 175–204.

CMPT (1999) 'A *Guide to Quantitative Risk Assessment for Offshore Installations", Centre for Maritime and Petroleum Technology'*, London: Routledge.

Du, Z.Feng (2018) 'Anewdata-drivendesignmethodologyformechanicalsystemswith high dimensional design variables' *Adv. Eng. Software* **117** (1), pp. 8–28.

Dinis, D., Teixeira, A. and Soares, C. G. (2020) 'Probabilistic approach for characterising the static risk of ships using Bayesian Networks (BN)', *Reliability Engineering & System Safety, 203*, pp. 107073.

Fan, L., Luo, M. and Yin, J. (2014) 'Flag choice and Port State Control inspections—empirical evidence using a simultaneous model', *Transport Policy*, **35**(1), pp. 350-357.

Fu, X Chen, S Wu, C Shi, H Wu, J Zhao (2020) 'Mining ship deficiency correlations from historical Port State Control (PORT STATE CONTROL (PSC)) inspection data', *Transport Policy*, **35**(1), pp. 350-357.

Flick, U. (2015) '*Introducing research methodology: A beginner's guide to doing a research project'*. Londong: Sage Publications.

Galvan, J. L. and Galvan, M. C. (2017) '*Writing literature reviews: A guide for students of the social and behavioral sciences'*. London: Routledge.

Gao, Z., Lu, G., Liu, M. and Cui, M. (2008) 'A novel risk assessment system for Port State Control inspection', *IEEE International Conference on Intelligence and Security Informatics.* Taipei: IEEE.

Goerlandt, F. and Montewka, J. (2015) 'A framework for risk analysis of maritime transportation systems: A case study for oil spill from tankers in a ship-ship collision', *Safety Science, **76**(1)*, pp. 42-66.

Gray, D. (2014) 'Theoretical perspectives and research methodologies. *Doing research in the real world'*. London: Routledge.

Hare, J. (1997) 'Port State Control: strong medicine to cure a sick industry', G*eorgia Journal of International and Comparative Law* **26** (3), pp. 571–594.

Hanninen, M. and Kujala, P. (2014) 'Bayesian network modelling of Port State Control inspection findings and ship accident involvement', *Expert System with Applications*, **41**(4), pp. 1632-1646.

Intercrop. Port State Control. A guide for ships involved in the dry bulk trades. Accessed December 2018 from https://www.mardep.gov.hk/en/others/pdf/Port_State_Control(PSC)guide.pdf

Heij, G.E. Bijwaard, S. Knapp (2011) 'Ship inspection strategies: effects on maritime safety and environmental protection', Tr*ansport. Res. Transport Environ* **16** (1), pp. 42–48,

Jin, W. Shi, K.F. Yuen, Y. Xiao, K.X. Li (2019) 'Oil tanker risks on the marine environment: an empirical study and policy implication', *Mar. Pol.* **108** (1), pp. 42–48.

Kesavaraj, G. (2013) *'A Study On Classification Techniques in Data Mining'*. Tiruchengode.

John, A., Yang, Z., Riahi, R. and Wang, J. (2016) 'A risk assessment approach to improve the resilience of a seaport system using Bayesian Networks (BN)', *Ocean Engineering*, **111,** pp 136-144.

Kara, N. (2016) 'Risk Assessment in the Istanbul Strait Using Black Sea MOU Port State Control Inspections', *Sustainability*, **8**(4), p. 390.

Knapp, S. and Franses, P.H. (2007) 'Econometric analysis on the effect of Port State Control inspections on the probability of casualty Can targeting of substandard ships for inspections be improved' *Marine Policy*, **31**, pp. 550-563.

Knapp, S. and Franses, P.H. (2007b) 'A global view on Port State Control - econometric analysis of the differences across Port State Control regimes', *Maritime Policy and Management* **34**, pp. 453-483.

Knapp, S. and Franses, P.H. (2007c) 'Econometric analysis on the effectiveness across Port State Control regimes – what are the areas of improvement for inspections?' O*cean Economics Review of China* **1**, pp. 26-54.

Knapp, S. and Franses, P.H. (2008) 'Econometric analysis to differentiate effects of various ship safety inspections', *Marine Policy* **32,** pp. 653-662.

Knapp, S. and Franses, P.H. (2009) 'Does ratification matter and do major conventions improve safety and decrease pollution in shipping?' *Marine Policy* **33,** pp. 826-846.

Kasoulides, G.C. (1993) 'Port State Control *and jurisdiction: evolution of the port state regime'*. Kluwer Academic Publishers: Dordrecht, Netherlands.

Kiehne, G. (1996) 'Investigation, detention and release of ships under the Paris Memorandum of Understanding on Port State Control: a view from practice', *The International Journal of Marine and Coastal Law* **11** (2), pp. 217–224.

Liou, S. T., Liu, C. P., Chang, C. C. and Yen, D. C. (2011) 'Restructuring Taiwan's Port State Control inspection authority', *Government Information Quarterly*, **28**(1), pp. 36-46, (2011)

Li, S., Meng, Q., and Qu, X. (2012) 'An overview of maritime waterway quantitative risk assessment models', *Risk Analysis*, **32(**3), pp. 496-512, (2012).

Li, K. X., Yin, J., Bang, H. S., Yang, Z., Wang, J., (2014) 'Bayesian network with quantitative input for maritime risk analysis', T**ransportmetrica A: Transport Science**, **10**(2), pp. 89-118.

McDorman, T.L. (2000) 'Regional Port State Control agreements: some issues of international law', *Ocean and Coastal Law Journal* **5** (2), pp. 207–225.

Mejia Jr., M.Q. (2005) 'Evaluating the ISM Code using Port State Control statistics', Lund University Department of Design Sciences, Lund, Sweden.

Mitroussi, K. (2004) 'Quality in shipping: IMO's role and problems of implementation', *Disaster Prevention and Management*, **13**(1), pp. 50–58.

Odeke, A. (1997) 'Port State Control and UK law', *Journal of Maritime Law and Commerce* **8**, pp. 657–665.

Owen, P. (1996) 'Port State Control and ship deficiencies', T*he International Journal of Shipping Law* **5** (1), pp. 267–274.

Ozcayir, Z.O. (2001a.) 'The role of Port State Control', *International Maritime Law* **8** (5), pp. 147–159.

Özçayır, N. (2009), 'The Use of Port State Control in Maritime Industry and Application of the Paris MoU', *Ocean and Coastal Law Journal* **14**(2), pp. 201-239.

Paris MoU. Paris MoU Annual Report (2017) 'Safeguarding responsible and sustainable shipping", Accessed December 2018 from https://www.parismou.org/2017-paris-mou-annual-report %E2%80%9Csafeguarding-responsible-and-sustainable-shipping%E2%80%9D

Paris MoU. (2014) 'Paris Memorandum of Understanding on Port State Control, incl. 37rd amendment (final)', Hague: Paris MoU

Paris MoU. (2014d). 'White, Grey and Black Flags List 2013', Hague: Paris MoU.

Payoyo, P.B. (1994) 'Implementation of international conventions through Port State Control: an assessment', *Marine Policy* **18,** pp. 379-392.

Qu, X., Meng, Q. and Li, S. (2012) 'Ship collision risk assessment for the Singapore Strait', *Accident Analysis and Prevention,* **43,** pp. 2030-2036.

Ravira, F. and Piniella, S. (2016) 'Evaluating the impact of PORT STATE CONTROL (PSC) inspectors' professional profile: a case study of the Spanish Maritime Administration', *WMU Journal of Maritime Affairs* **15** (2), pp. 221–236.

Seatrademaritimeevents.com. (2020) *'Technology in Maritime: Eight Emerging Trends That You Need to Know for 2020'*. Retrieved from https://www.seatrademaritimeevents.com/shiptech/en/reports-and-insights/eight-emerging-maritime-technologies.html

Shen et al , Q. (2003) 'The Design and Implementation of Automatic Ship Selection in Port State Contro', *Shipping Management* **3**(2), pp. 32-34.

Sullivan, L. M., Weinberg, J. and Keaney, J. F. (2016) 'Common Statistical Pitfalls in Basic Science Research' *J Am Heart Assoc, **5***(10), pp. 32-34.

Tranfield, D. and Denyer, P. (2003) 'Towards a methodology for developing evidence-informed management knowledge by means of systematic review', B*ritish Journal of Management* **14**(2), pp. 207-208.

Van Leeuwen (2015) 'The regionalization of maritime governance: Towards a polycentric governance system for sustainable shipping in the European Union', *Ocean & Coastal Management* **117** (2), pp. 23-31.

Webster, J. & Watson, R.T. (2002) 'Analyzing the past to prepare for the future: Writing a literature revie', *Management Information Systems Quarterly,* **26**, p. 3

Whittemore, K. and Knafl, R. (2005) 'The integrative review: Updated methodology', *Journal of Advanced Nursing*, **52,** pp. 546-547.

Wisse, B.W., van Gosliga S.P., van Elst N.P., Nonnecke, B. (2008) 'Relieving the elicitation burden of Bayesian belief networks', 6th Bayesian Model. Applic. Workshop on UAI.

Wu et al , B. (2015) 'Effectiveness of maritime safety control in different navigation zones using a spatial sequential DEA model: Yangtze River case', *Accident Analysis & Prevention* **3**(1), pp. 232-242.

Xu, R. (2007) ;A Risk Assessment System for Improving Port State Control Inspection', *IEEE*, 15.

Xu, R.-F., Lu, Q., Li, W.-J., Li, K. and Zheng, H.-S. (2007) ;A Risk Assessment System for Improving Port State Control Inspection', *2007 International Conference on Machine Learning and Cybernetics.* Hong Kong: IEEE.

Yang et al , Z. (2018) ;Realising advanced risk-based Port State Control inspection using data-driven Bayesian Networks (BN)', *Transportation Research Part A: Policy and Practice*, pp. 38–56.

Yang, et al , Z. (2018) ;A risk-based game model for rational inspections in Port State Control', *Transportation Research Part E: Logistics and Transportation Review*, 477–495.

Yang, Z. (2018) 'Risk-Based Game Modelling for Port State Control Inspections', *ransportation Research Part E: Logistics and Transportation Review*, **5**(1), pp. 1-20.

Yang, Z, Yang, Z, Yin, J and Qu, Z (2018) 'A risk-based game model for rational inspections in Port State Control', Tr*ansportation Research Part E: Logistics and Transportation Review*, **118** (1), pp. 477-495.

Yang Z.L., Wang J. and Li K. (2013) 'Maritime safety analysis in retrospect', *Maritime Policy and Management*, **40**(3), pp. 261-277.

Zhang, D., Yan, X.P., Zhang, J.F., Yang, Z. and Wang, J. (2016) 'Use of fuzzy rule-based evidential reasoning Approach in the navigational risk assessment of inland waterway transportation systems', *Safety Science*, **82,** pp. 352-260.

Zhong et al , G. (2008) 'A novel risk assessment system for Port State Control inspection', *IEEE International Conference on Intelligence and Security Informatics*.