Journal of
Marine Science and Engineering

MDPI

Article

Port State Control Inspections under the Paris Memorandum of Understanding and Their Contribution to Maritime Safety: Additional Risk Classifications and Indicators Using Multivariate Techniques

David Almorza [1], Jose Manuel Prieto [2,*], Víctor Amor-Esteban [3] and Francisco Piniella [2]

[1] Department of Statistics and Operational Research, University of Cádiz, 11003 Cadiz, Spain; david.almorza@uca.es
[2] Department of Maritime Studies, University of Cádiz, 11003 Cadiz, Spain; francisco.piniella@uca.es
[3] Department of Statistics, University of Salamanca, 37008 Salamanca, Spain; vamor@usal.es
* Correspondence: josemanuel.prieto@gm.uca.es

Abstract: Port State Control (PSC) inspections conducted under the Paris Memorandum of Understanding (MoU) agreement have become a crucial tool for maritime administrations in European Union countries to ensure compliance with international maritime safety standards by ships entering their ports. This paper analyses all PSC inspections conducted in 10 major European ports belonging to the Paris MoU between 2012 and 2019. For its study, a multivariate HJ-Biplot statistical analysis is carried out, which facilitates the interpretation and understanding of the underlying relationships in a multivariate data set by representing a synthesis of the data on a factorial plane, with an interpretation that is very intuitive and accessible for readers from various fields. Applying this method with ship characteristics as explanatory variables, several classifications were derived. These classifications align with the annual performance lists published by the Paris MoU and the International Association of Classification Societies list, suggesting that this method could serve as a reliable classification approach. It provides maritime authorities with an additional indicator of a ship's risk profile, aiding in the prioritising of inspections. The method also effectively categorises ports and types of ships used for cargo transport, offering insights into the specific maritime traffic each port experiences. Furthermore, this study identifies characteristics associated with substandard ships, which is a primary objective of PSC inspections. Beyond revealing these traits, this research underscores the existence of several readily applicable techniques to enhance maritime safety and reduce the risk of ocean pollution.

Keywords: maritime safety; Port State Control; Paris MoU; multivariate statistical HJ-Biplot

check for updates

Citation: Almorza, D.; Prieto, J.M.; Amor-Esteban, V.; Piniella, F. Port State Control Inspections under the Paris Memorandum of Understanding and Their Contribution to Maritime Safety: Additional Risk Classifications and Indicators Using Multivariate Techniques. *J. Mar. Sci. Eng.* **2024**, *12*, 533. https://doi.org/10.3390/jmse12040533

Academic Editor: Xinqiang Chen

Received: 4 March 2024
Revised: 20 March 2024
Accepted: 20 March 2024
Published: 23 March 2024

1. Introduction

Globalisation relies heavily on maritime transport. However, the growth of this sector has led to the widespread use of open registries, referred to by the International Transport Federation as "flags of convenience", with Panama as an example [1]. This shift has transformed the worldwide scenario, necessitating modifications to the systems employed to enforce adherence to the international regulatory principles set forth by the International Maritime Organization. These adjustments particularly pertain to safety and pollution prevention measures [2].

The primary challenge confronting the international community in light of the substantial migration of over half of the global fleet to Flags of Convenience is related to maritime safety [3]. These host countries, grappling with a significant number of vessels registered under their flags, face limitations in conducting thorough safety assessments due to either insufficient resources or deficiencies in their fleet inspection policies [4]. This oversight responsibility is delegated to classification societies, also known as recognised organisations (ROs), some of which exhibit notably low-quality standards concerning the safety oversight of ships. Both of these phenomena are closely intertwined and progress in tandem, encompassing the proliferation of "flags of convenience" and the transfer of safety inspection procedures from flag states to ROs.

In order to ensure compliance with safety protocols, the global community established regulatory mechanisms involving routine inspections of ships in ports. This initiative culminated in the creation of the Paris Memorandum of Understanding (Paris MoU) in 1982, which established Port State Controls (PSCs). These controls involve inspections of foreign vessels conducted by the maritime administration of a specific country. During the initial inspection, the inspectors examine the statutory certificates that verify compliance with international conventions such as SOLAS, MARPOL, STCW, and others. If the initial inspection gives rise to concerns regarding non-compliance, a more thorough examination may be conducted to confirm the vessel's adherence to safety standards. In the event of non-compliance with international regulations, and contingent upon the severity of identified deficiencies, the vessel may be subject to detention by the respective maritime administration [5–7].

The PSC inspection framework is devoid of global standardisation and is instead fragmented into regions, each operating under its respective Memorandum of Understanding [8]. This study focuses on the Paris MoU region, which includes the European Union (EU). The oversight of inspections of foreign ships within this region is governed by several directives, the most recent of which is 2009/16/EC (ERIKA III). This directive introduces new provisions aimed at coordinating and standardising PSC inspections across Europe. This system, implemented in 2011, standardised the criteria for PSC inspections, establishing a coordinated system of maritime safety inspections to avoid disparities in inspection procedures in EU ports. Moreover, the latest regulatory provisions have harmonised the standards for vessel detention [9], ensuring uniform enforcement and avoiding the clustering of maritime traffic in particular ports. This will deter shipping companies from exploiting lax inspections and profiting from inadequate oversight.

The inspection system uses a "prioritised inspections" approach. This means that each ship is assigned a "risk profile" based on factors such as previous inspection results, the shipping company, and the flag state. Inspectors are then informed in real time about the priority and type of inspection required for each vessel. There are three types of inspections that can be applied to a ship as follows: Initial Inspection, More Detailed Inspection, and Expanded Inspection. Each of these has its own characteristics and will depend on the type of ship being inspected, its risk profile, and priority and contingency factors. This regulation standardises criteria for ship immobilisation and detention and establishes a coordinated system aimed at harmonising inspection procedures across EU ports to prevent disparities.

The inspections are closely linked to THETIS [10], a data system overseen by the European Maritime Safety Agency (EMSA). THETIS systematically evaluates all PSC inspections carried out in the EU and generates a risk profile for each ship derived from historical results. This profile establishes inspection criteria to help maritime administrations prioritise ship inspections. In addition, THETIS is integrated with the European network SafeSeaNet, providing an additional layer of assurance in its implementation and monitoring.

Review of the Latest Studies on Safety Controls

Brooks [11] observed a discernible shift towards privatisation in maritime safety oversight. Håvold [12] emphasised the central role of quantitative risk analysis in the development of maritime safety. The seminal work of Knapp and Frances [8,13,14] involved the pioneering use of econometric methods to identify differences among inspection systems. Their proposals, which advocated for adjusting inspection frequencies according to the risk profiles of ships, were effectively incorporated into the Paris MoU. The comprehensive review of the New Inspection Regime (NIR) implemented in 2011 was thoroughly reviewed by [15–17].

The study conducted by Li and Zheng [4] assessed the efficiency of the system and methodologies employed by regional Port State Control (PSC) agreements in choosing ships for inspection. Recent investigations, including those by [18,19], employed Bayesian networks to explore the relationship between PSC inspections and the incidence of maritime accidents. Similarly, the works of Özçayir [20] and Wu et al. [21] used a similar approach to investigate this relationship.

Knapp and Frances [8] asserted that the outcome of an inspection is significantly impacted by the professional profile of the inspector. They concluded that the probability of arrest varies depending on the inspector's previous experience. Ravira and Piniella [22] concluded in a recent study that the outcome of inspections is influenced by professional training and the use of teams. Their study highlights the crucial role of professional training and team collaboration in conducting inspections.

Graziano et al. [23] analysed 25 inspection reports generated by EMSA, scrutinising inspections conducted by Member States to evaluate the degree of implementation, compliance, and alignment with Directive 2009/16/EC [24]. Their study aimed to identify discrepancies between the directive's prescribed policy and the practical application of inspections. Furthermore, the paper [23] assessed the divergences between Member States following the implementation of the directive and the New Inspection Regime (NIR).

Wang et al. [3] introduced a Bayesian network classifier using the Tree Augmented Naive Bayes method to identify high-risk foreign ships present in ports. This classifier serves as an additional tool for PSC authorities to detect ships with lower compliance standards, allowing a more strategic allocation of inspection resources. Chen et al. [25] conducted an empirical analysis of detention data collected from Asia-Pacific port states (Tokyo MoU) over the last decade. Their study aimed to provide practical measures for port states to improve the effectiveness of ship safety inspections.

A recent study [26] highlighted the potential for improvement in the identification of ships for inspection and the delineation of priority areas. Applying this approach can help maritime administrations categorise the risk associated with ships and select inspection targets. The current research builds on these efforts by classifying ships based on their risk profiles, providing an additional indicator for the selection of inspection targets.

Yuhong-Wang et al. [27] utilised a probabilistic risk model to explore the risk factors linked with Port State Control (PSC) inspections. Their study applied Bayesian Network analysis and utilised comprehensive data from Tokyo MoU inspections conducted between 2014 and 2017 to examine the dependence and interdependence of these factors. Their study identified safety deficiencies and technical characteristics of ships as the most crucial factors influencing PSC inspections and subsequent detentions.

Prieto et al. [28] conducted a thorough analysis of inspections carried out between 2013 and 2018 in the top European ports of the Paris MoU, utilising multivariate statistics (STATIS). Through this analysis, they were able to derive flag and company classifications that were in alignment with the annual lists published by the Paris MoU. Their study validates the effectiveness of a classification method that employs multivariate techniques. The research outcomes provide a valuable indicator for maritime administrations to assess a ship's risk profile and make informed decisions regarding inspection priorities. In this sense, the current work presented in this document is partly consistent with these results but uses a different multivariate technique, namely, the HJ-Biplot.

Liu et al. [29] confidently assessed detention risk by identifying the factors that determine it using a Bayesian network technique with PSC training data. The results provide valuable information for shipowners to proactively manage detention risk and assist port authorities in prioritising the ship's checklist and conducting more efficient inspections.

In their study of data comprising 71,376 defect records with 496 defect codes across 21 ship types within the Paris MoU, Lai et al. [30] applied grey relational analysis and the technique of order preference by similarity to the ideal solution. The mechanism developed in their paper for concentrated inspection campaigns can effectively identify substandard ships. Their research is innovative in its use of multivariate techniques to identify ships below the required safety levels.

A recent study on pollution caused by maritime transport calculated pollutant emissions in 30 United States ports during 2021 [31]. The study used an Automatic Identification System (AIS) data record and applied the geographically weighted multiscale regression model to analyse the factors that affect pollutant emissions from ships. The data suggested that there is a disparity in the distribution of ship pollutant emissions across different ship types and ports. It was recommended that port managers take this into account when planning the number of ship transactions based on the length of the port's coastline. Another study also used AIS as a database and used it to recognise maritime traffic patterns in the Beibu Gulf [32]; their analysis provides a theoretical framework for improving methods of identifying shipping channels for maritime transport management. Finally, in terms of marine environmental protection, a recent study [33] examined the impact of oil spills in the Arctic region using an analytical network-supported ensemble (ANP) and a fuzzy integral assessment model as a methodology. Their results accurately quantified the impact of an oil spill in the Arctic area, allowing for the accurate identification of potential risks.

Currently, there are advantages to the PSC inspection system; however, maritime and port authorities must investigate the optimisation of existing resources for vessels that are susceptible to breaching safety and pollution prevention standards.

In this study, using PSC inspections conducted within the Paris MoU in the last few years, the objective is to differentiate ship profiles using classifications, by way of a multivariate statistical HJ-Biplot analysis. In addition, this study aims to determine if maritime traffic and inspections differ between the chosen ports and classify them accordingly.

This paper follows a clear structure. Section 2 furnishes an in-depth account of the database, along with the methodologies and techniques employed. Section 3 delineates the outcomes, while Section 4 encapsulates the conclusion of this paper.

2. Methodology

The sample for this study consists of PSC inspections carried out in major European ports from 2012 to 2019. Specifically, the analysis focuses on inspections conducted post-implementation of the "prioritized inspections" in the Paris MoU. These prioritised inspections were introduced to replicate successful practices observed in other international ports employing a similar system. The "prioritized inspections" involve establishing a "risk profile" for ships based on factors such as shipping company, flag, and outcomes from previous inspections (available in THETIS). This information is then used to inform maritime administration and PSC inspectors automatically about inspection priorities and required types.

2.1. Data Description

The inspection data for the period 2012–2019, as mentioned in the Introduction, were sourced from the THETIS platform [10]. Specifically, the data from 2019 were utilised in the validation test of the classified model generated through multivariate HJ-Biplot analysis.

Data were only included up to 2019 to provide stability in the data because the COVID-19 epidemic declared in 2020 had a major impact on maritime transport [34] and, consequently, on PSC inspections, with anomalies in inspection procedures being detected [35].

The investigation examined the 10 most notable ports involved in the Paris MoU over the study period. The selection criteria were established based on the highest volume of transported goods, sourced from the Eurostat database [36]. The variables used in this study are the characteristics of the inspected vessel (Table 1) and the results of the inspection in port (Table 2).

Table 1. Variables that describe the inspected ship.

Ship Variables	Description
Classification Certificates	Classification society Recognised Organisation. Certifies the ship is in good condition. Chosen by the ship owner.
Flag	Country of registry Country where the ship is registered (chosen by the ship owner).
Age	Age of the ship
Ship-type description	Type of ship Depending on purpose: container, sil tanker, etc.
Gross tonnage	Registered gross tonnage GT A dimensional number that indicates ship size.

Source: [28].

Table 2. Variables that describe the inspection.

Inspection Variables	Description
Port	Port where the inspection is conducted
Type of inspection	Type of inspection a ship undergoes The type and depth of inspection depend on the ship's risk profile and the priority factor.
Number of deficiencies	Number of deficiencies found during inspection

Source: [28].

2.2. HJ-Biplot Analysis

Biplot analyses comprise a set of exploratory techniques for dimension reduction of data matrices; they can be understood as a multivariate scatterplot. The purpose of these methods is the representation of matrix data in a factorial plane, where the relationships among the variables (columns of the matrix) can be interpreted, at the same time as the characterisation of individuals (rows of the matrix) based on of their values in said variables. Gabriel [37] proposed the following methods known as classic biplot methods: GH-biplot and JK-biplot, with optimal quality of representation for columns or rows, respectively. Later, Galindo [38] developed the HJ-Biplot, a technique that gathers the ideas of Gabriel's biplot [37], with the principal objective of representing the data matrix with the same quality of representation for both rows and columns in the same factorial plane.

The HJ-Biplot focus of this research was to characterise the different categories of the nominal qualitative variables with respect to their quantitative variable values. The idea was to identify if there are different profiles based on a ship's dimensions, number of identified deficiencies, inspection type, and age and if these characteristics vary depending on ship type, country of registry, inspection class, or port of inspection.

For this method, a matrix X is decomposed in a singular value decomposition as X = UDVT where $D = diag(\lambda_1, \ldots, \lambda_p)$ contains the singular values and U and V are orthogonal matrices. In addition, H and J are the matrices of the first two columns of VD and UD, respectively. The objective of this technique is the representation of the data of the matrix $X_{n \times p}$ in this reference subspace, where the columns of the matrix are represented by vectors and the rows by points. Thus, the HJ-Biplot manages to superimpose the columns of the matrix from the markers $h_j = (h_j, \ldots, h_p)$ and the rows through the markers $j_i = (j_i, \ldots, j_n)$ with the same quality of representation in the same reference subspace.

To apply this method correctly, it is important to follow certain steps to interpret the HJ-Biplot elements. In this article, four biplot analyses were carried out, where the main objective was to describe the relationships between the rows (flag, ship type, inspection class, and port of inspection), which are graphed by points in two-dimensional space, and the columns (variables that evaluate the profile of the rows, ship's dimensions, number of identified deficiencies, inspection type, and age), which are graphed as vectors in two-dimensional space.

This method allows the user to perform the following:

(i) Identify groups of rows with similar profiles, for example, the distance between the points on the plane is relative to the differences between profiles, where the shorter the distance, the lower the dissimilarities. This means that points close together on the plane have similar characteristics for the chosen variables.

(ii) Evaluate relationships between variables, where acute angles are associated with direct correlations and the more acute the angle, the more intense the correlation. Right angles indicate independent variables and obtuse angles indicate inverse correlations. This means, for example, that vectors on the plane that form acute angles are directly correlated.

(iii) Classify the rows—points on the plane—with respect to each variable—vectors on the plane. This is performed by arranging the rows with respect to each variable through the order of the orthogonal projections of the points onto the vectors.

Galindo's HJ-Biplot has been applied in several fields including histopathology [39], oenology [40], limnology [41], biotechnology [42], bibliometry [43], sociology [44], and sustainability [45–47]. This method offers an effective and powerful way to visualise multivariate data, allowing for a deeper and more complete interpretation of the information contained in a data table. Among the merits of this technique, its results stand out with a clear and concise visual representation of the relationships between observations and variables in a single two-dimensional graph, which facilitates the interpretation of the data in a very intuitive way and in an accessible language for readers from different fields. The HJ-Biplot simplifies the information, reduces the dimensionality of the data, and synthesizes the information in a single graph, which allows for identifying patterns and structures in multivariate data, such as groupings, trends, and relationships between variables and observations, which helps to better understand the information being processed. It should be noted that the HJ-Biplot is primarily an exploratory and descriptive method, which means that it can provide a visual representation of the current information situation, facilitating the characterisation of risk profiles. Thus, it can be used as a complementary indicator to assist in the establishment of priorities in the different PSC inspections, but it cannot necessarily be used to make statistical inferences or establish causal relationships. To carry out these analyses, MultBiplot software developed by Vicente-Villardón [48], was used.

3. Results and Discussion

In this section, different results are listed based on the chosen nominal qualitative variable. As a first step, all the inspections were analysed solely based on the quantitative variables to give an overview of the data.

3.1. Biplot Representation of all PSC Inspections 2012–2019

First, for purely exploratory purposes, the full sample, i.e., all the inspections conducted in the studied ports between 2012 and 2019, is presented (Figure 1). For this, an HJ-Biplot analysis was performed to represent all of the individual PSC inspections (individuals; rows in the data matrix) based on their characteristics, age, ship dimensions, inspection type, and number of deficiencies found (variables; columns of the data matrix).

To correctly apply the HJ-Biplot method, it is essential to consider several measures, such as eigenvalues and explained variance (Table 3) and the relative contribution of the factor to the element (Table 4). These measures assist in pinpointing the variables accountable for the axis positions and the resultant configuration.

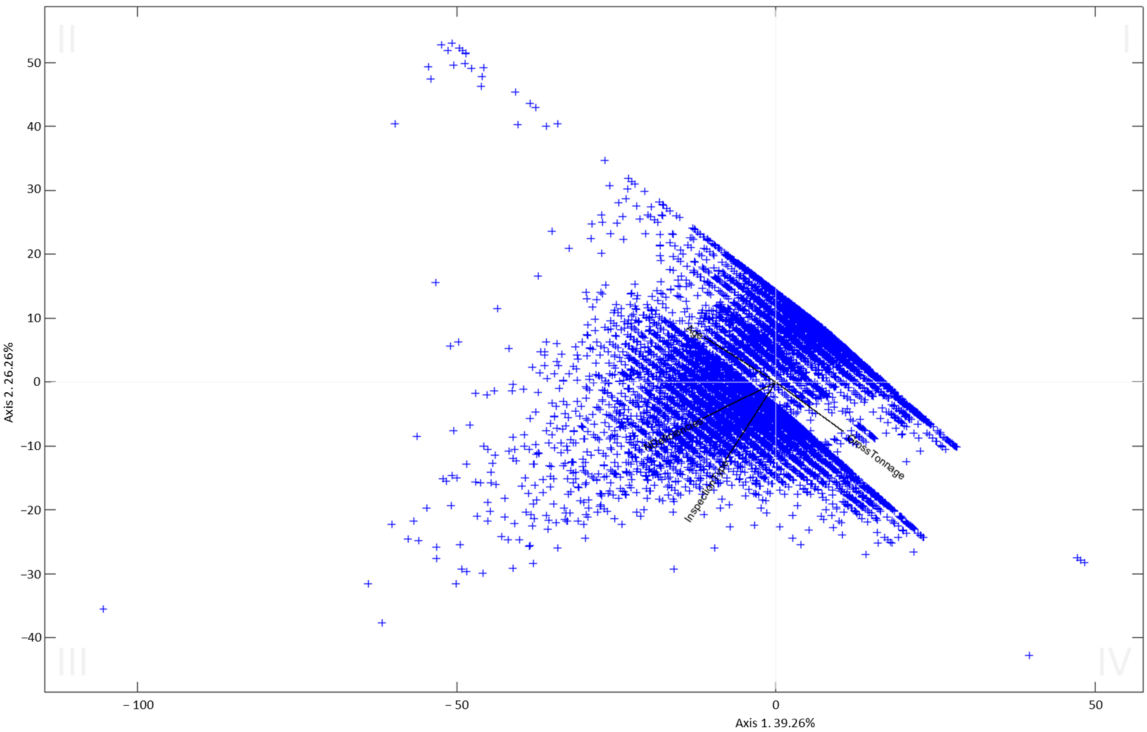

Figure 1. HJ-Biplot representation of PSC inspections between 2012 and 2019.

Table 3. Eigenvalues and explained and accumulated variance of all PSC Inspections 2012–2019

Axis	Eigenvalue	%Variance	%Accumulated
Axis 1	29,928.14	39.26	39.26
Axis 2	20,014.96	26.26	65.52
Axis 3	13,713.86	17.99	83.50
Axis 4	12,575.04	16.50	100.00

Table 4. Relative contribution of each factor to each element of all PSC Inspections 2012–2019

Variable	Axis 1	Axis 2
GrossTonnage	407	623
Age	458	639
InspectionType	223	758
NDeficiencies	482	600

Naturally, the representation of such a high number of individuals makes interpretation difficult. What can be seen is that the data are distributed throughout the plane, showing a rich variability, an aspect that is of vital importance when carrying out a multivariate analysis. This translates to mixed traffic in the studied ports, that is to say, inspections are performed on new ships with generally few deficiencies, old ships with generally a lot of deficiencies, and also on medium-sized ships with a variety of deficiencies.

Likewise, hidden behind the points is the structure made by the study variables (Figure 2), which indicates the position of the inspections and the points on the plane. The correlation between variables can be seen in the angles formed by the vectors; acute angles indicate direct relationships; right angles, close to 90°, refer to independent variables; and obtuse angles show inverse relationships. There is therefore a correlation between the age of a ship and the number of deficiencies; in particular, older ships are more likely to have a higher number of deficiencies.

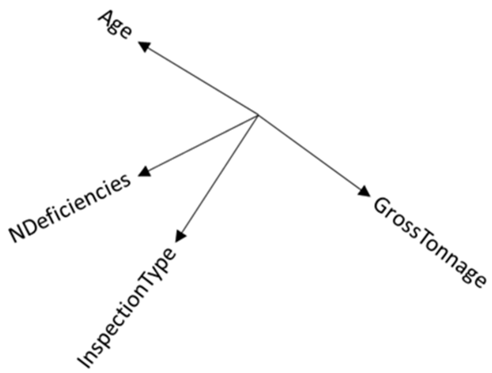

Figure 2. Structure made by this study's PSC inspection variables between 2012 and 2019.

There is also an inverse relationship between ship age and its gross tonnage; the older the ship, the smaller its dimensions are and, as seen before, the greater the number of deficiencies. These two results combined show a typical substandard ship's profile. By contrast, the younger the ship, the bigger its dimensions, which can be associated with the worldwide tendency to build bigger ships continuously. A clear example is that of container ships, oil tankers, and noxious liquid substances tankers, which are ships that have proliferated in number and size in the last decade and that will be discussed in the next section.

To obtain specific conclusions, the following sections provide representations referring to the country of registry, inspection class, ship type, and port of inspection.

3.2. Biplot Representation of the Country of Registry of the Studied Ships

In this section, with the use of an HJ-Biplot, the country of registry of the studied ships will be projected onto the variables that record the ship's dimensions, age, inspection type, and number of deficiencies found. Thus, it is possible to characterise each country of registry based on these parameters and, therefore, find the main distinguishing differences.

As in Section 3.1, the eigenvalues and explained variance (Table 5) and the relative contribution of the factor to the element (Table 6) were calculated. This makes it possible to identify the variables responsible for the axis positions and thus the configuration of the factorial plane.

Table 5. Eigenvalues and explained and accumulated variance of the Country of Registry

Axis	Eigenvalues	%Variance	%Accumulated
Axis 1	215.73	59.93	59.93
Axis 2	72.80	20.22	80.15
Axis 3	42.31	11.75	91.90
Axis 4	29.15	8.10	100.00

Table 6. Relative contribution of each factor to each element of the Country of Registry

Variable	Axis 1	Axis 2
GrossTonnage	615	165
Age	710	99
InspectionType	393	519
NDeficiencies	678	26

All the variables contribute substantially to the construction of the first two factorial axes. Gross tonnage, age, and the number of deficiencies have a higher weight on the first axis, and inspection type has a higher weight on the second axis. In addition, the first two axes explain 80% of the data variability. For this reason, the factorial plane made up of 1 and 2 will be used to represent the countries and variables (Figure 3).

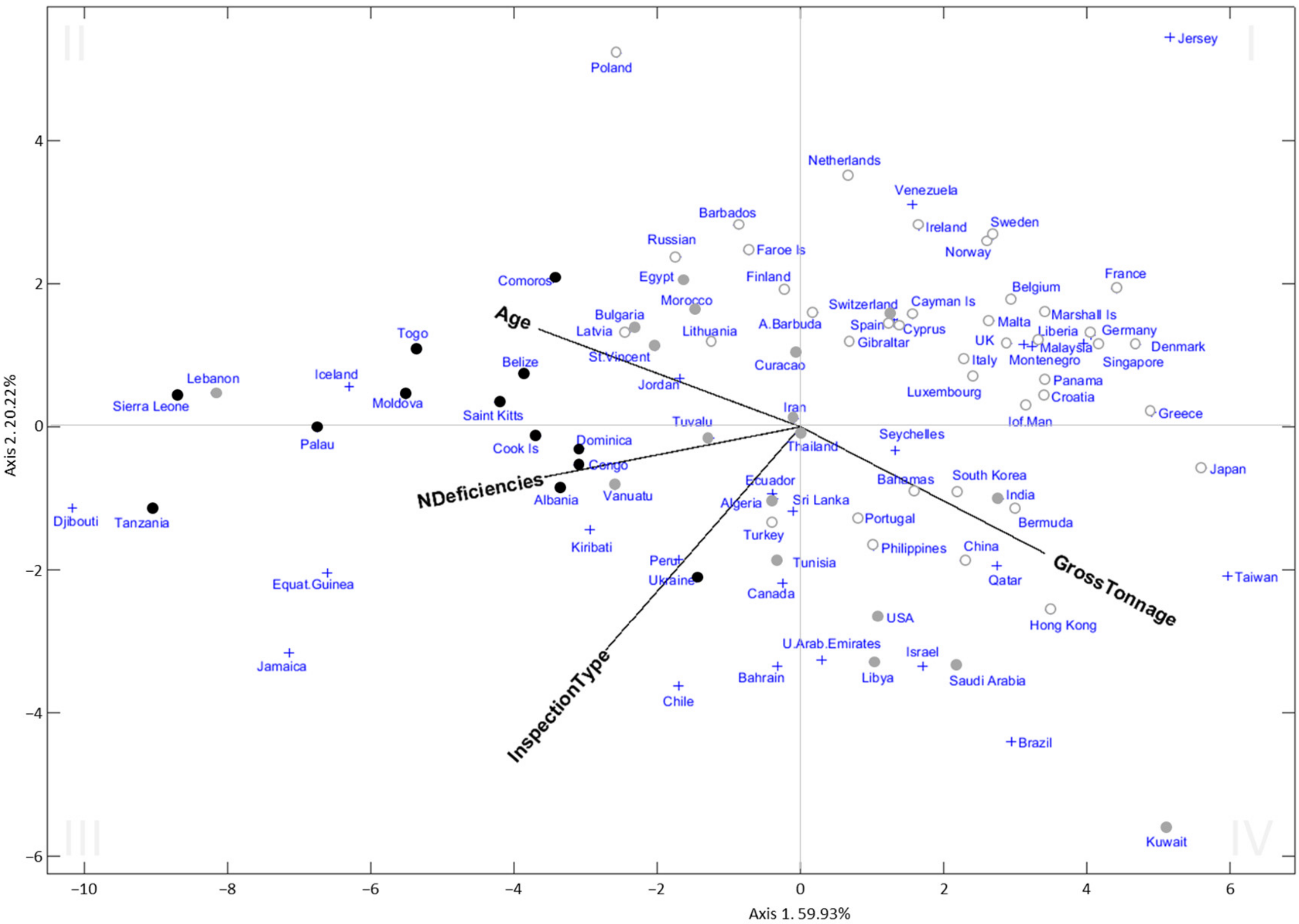

Figure 3. HJ-Biplot representation of the country of registry.

The 93 countries are distributed throughout the plane, which means that there are differences depending on where the ships are registered. The structure of the variables is maintained, i.e., the angles between vectors are similar to those in Section 3.1, although in this case, the relationship between the number of deficiencies and the ship's age is accentuated.

Thus, the countries situated on the right semi-plane have younger ships, which are also those with higher gross tonnage. These countries include, for example, Kuwait, Taiwan, Japan, Hong Kong, and Brazil (e.g., Kuwait ships on average have fewer than one deficiency, are 4 years old, and are 101,918 gross tons; in Taiwan, the ships on average have one or no deficiencies, are 2 years old; and are 83,684 gross tons).

Furthermore, countries in the upper-right half of the semi-plane (first quadrant) have a lower number of shortcomings. These countries include, for example, Belgium, Denmark, France, Germany, Norway, Low Countries, Ireland, the U.K., and the Isle of Man, as well as others such as Malaysia, Singapore, Japan, Taiwan, and the Marshall Islands. All these countries are found on the white list of the Paris MoU [49]; they have new ships with few deficiencies and are represented by a white dot in reference to this list. All these results coincide to serve as a verification of the method.

Another group can be found on the left semi-plane, where grey and black points are situated, which refer to their position on the Paris MoU lists. On the left semi-plane are the countries with older ships, smaller dimensions, and a higher number of deficiencies. The further the point is to the left of the plane, the worse the characteristics are. Countries such as Tunisia, Algeria, Thailand, and Iran, which are near the vertical axis, have ships that are approximately 12 years old, with between four and six deficiencies and a maximum of 25,000 gross tons. Other countries like Egypt, Morrocco, Tuvalu, Saint Vincent and the Grenadines, Bulgaria, and Vanuatu, which are found further to the left, have ships that are on average 22 years old, with between five and seven deficiencies, and a maximum gross tonnage of less than 18,000 tons (except Tuvalu, whose gross tonnage is close to 30,000 tons). All of these countries are found on the Paris MoU grey list [49].

Lastly, the countries found on the Paris MoU blacklist are the leftmost points on the plane, which have the worst characteristics. These are countries such as Albania, Congo, the Dominican Republic, the Cook Islands, San Cristobal Island (a.k.a. Chatham), Belize, and Comoros. The majority of these have ships with more than seven deficiencies, an average age of 25 years or more, and a gross tonnage mostly under 7000 tons (except the Dominican Republic, with 18,000 tons). It is important to note that Vanuatu (grey list in 2018) was placed on the blacklist in previous years. Other more extreme cases are those of Moldova, Togo, Palau, Tanzania, and Sierra Leone, which have ships with more than 10 deficiencies, an average age of over 30 years, and a gross tonnage below 5000 tons. Lebanon (grey list in 2018) should be mentioned because it was previously on the blacklist and has similar characteristics to these countries.

The derived classification is consistent with the performance lists published by the Paris MoU throughout the study period [49]. Therefore, this method may be appropriate for future flag classification or for flags that have not yet been classified. For instance, Djibouti, Iceland, Equatorial Guinea, and Jamaica have not been classified yet, but they could be included in the Paris MoU blacklist as they share similar characteristics with those mentioned.

The efficacy of the methodology as a classifier was affirmed through a validation process, involving a comparison of the outcomes from this section with the 2019 performance list [49].

3.3. Biplot Representation of the Different Types of Ships Found in This Study

Following a similar procedure to the previous section, 'ship type' was projected as a variable onto the variables that evaluate ship dimensions, age, inspection type, and number of deficiencies found. The main objective is to identify if ship type is related to a higher number of deficiencies or if it is irrelevant.

Of the 23 types of ships found in this study, only those with a minimum of 10 ships were selected for analysis, which left a total of 20 different types (leaving out 'commercial yacht', 'high-speed cargo' and 'livestock carrier'). Before presenting the HJ-Biplot representation, the measures used to interpret them correctly are shown including the eigenvalues and explained variance (Table 7) and the relative contribution of the factor to the element (Table 8). With the first two factorial axes, 76% of the total information is explained; therefore, these are used in the following representation (Figure 4).

Table 7. Eigenvalues and explained and accumulated variance of ship type.

Axis	Eigenvalues	%Variance	%Accumulated
Axis 1	36.16	47.58	47.58
Axis 2	21.66	28.50	76.08
Axis 3	12.94	17.03	93.11
Axis 4	5.24	6.89	100.00

Table 8. Relative contribution of each factor to each element of ship type.

Variable	Axis 1	Axis 2
GrossTonnage	375	253
Age	238	441
InspectionType	484	401
NDeficiencies	806	45

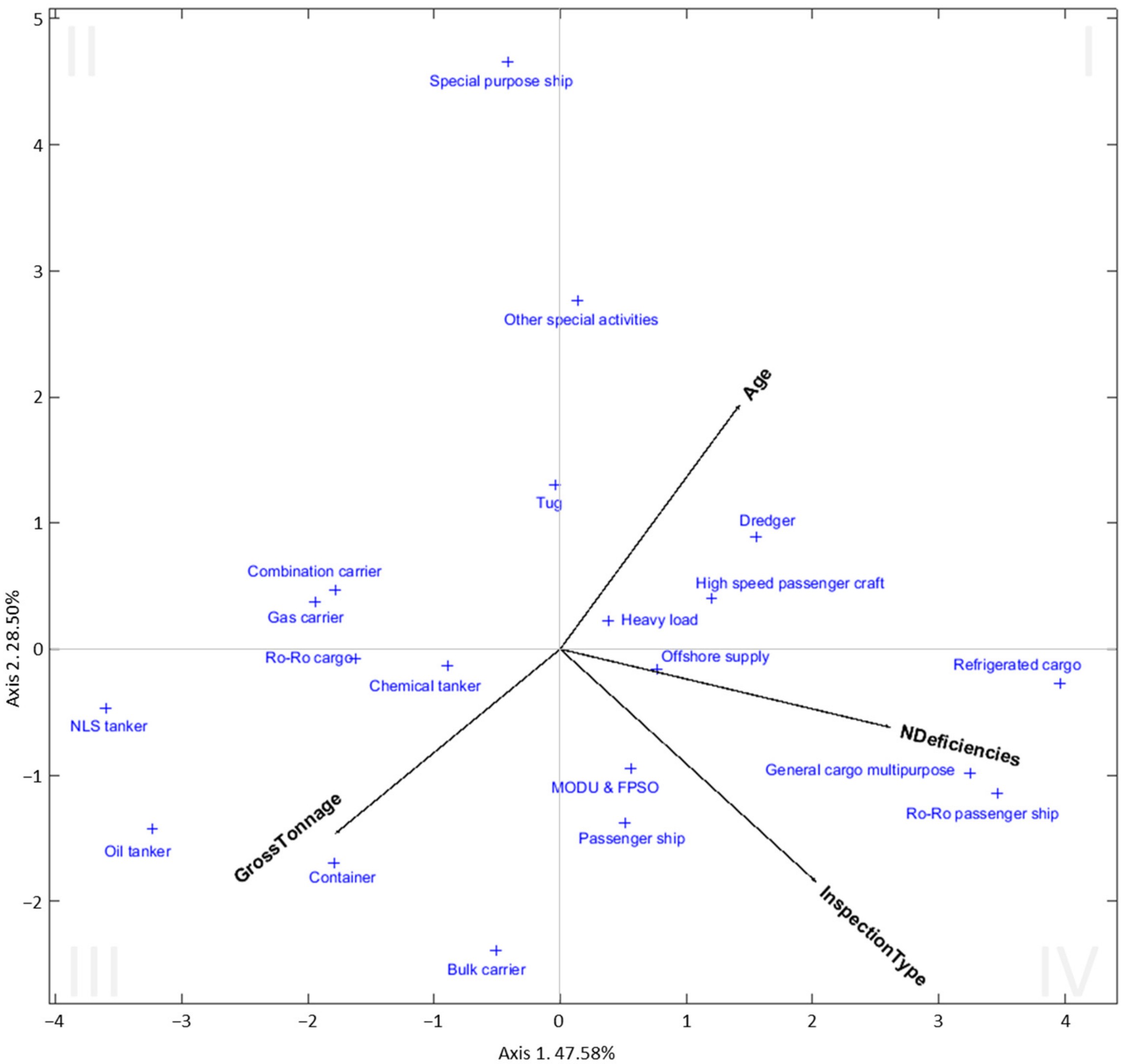

Figure 4. HJ-Biplot representation of ship type.

The different types of ships are found in different areas on the plane; therefore, there are differences in the variables depending on ship type. The structure of the variables is maintained, accentuating the relationship between the number of deficiencies and the type of inspection. Table 8 shows the contribution of the variables to the axes, where the number of deficiencies has a higher weight on the horizontal axis. This means that more problematic ships will be located on the right side of the plane, which includes ships such as 'refrigerated cargo', 'Ro-Ro passenger ship', and 'general cargo multipurpose'; conversely, those found on the left are less problematic ships with fewer deficiencies, like 'NLS tanker', 'oil tanker', 'gas carrier' or 'container'.

The majority of ship types are found away from the origin, which means that the representation is of optimal quality. In the upper semi-plane, the ships are older and of smaller dimensions like 'special-purpose ships' or 'other special activities'; conversely, the newer and bigger ships are found in the third quadrant, such as 'oil tankers', 'containers', 'bulk carriers' or 'NLS tankers'.

The bulk carrier stands out because it is one of the bigger ships and also has an important number of deficiencies.

The use of this methodology in the future could assist in examining how the fleet ages and how the maritime traffic changes in these ports based on ship type.

3.4. Biplot Representation of the Different Classification Societies Recorded in PSC Inspections

The PSC inspections can be differentiated by their classification societies; for this investigation, the data are heterogeneous and are made up of 30 different certificates. The process is similar to the previous sections but in this case, the classification societies are projected onto the variables that evaluate ship dimensions, age, inspection type, and number of deficiencies found, and the HJ-Biplot analysis searches for the similarities and differences between them. To interpret the analysis correctly, the eigenvalues and explained variance (Table 9) are given, as well as the relative contribution of the factor to the element (Table 10). The first two factorial axes explain 88% of the total information, and, therefore, are the two axes represented (Figure 5).

Table 9. Eigenvalues and explained and accumulated variance of Classification Societies

Axis	Eigenvalues	%Variance	%Accumulated
Axis 1	85.50	76.34	76.34
Axis 2	13.98	12.48	88.82
Axis 3	9.21	8.22	97.04
Axis 4	3.32	2.96	100

Table 10. Relative contribution of each factor to each element of Classification Societies

Variable	Axis 1	Axis 2
GrossTonnage	822	119
Age	812	82
InspectionType	760	29
NDeficiencies	660	269

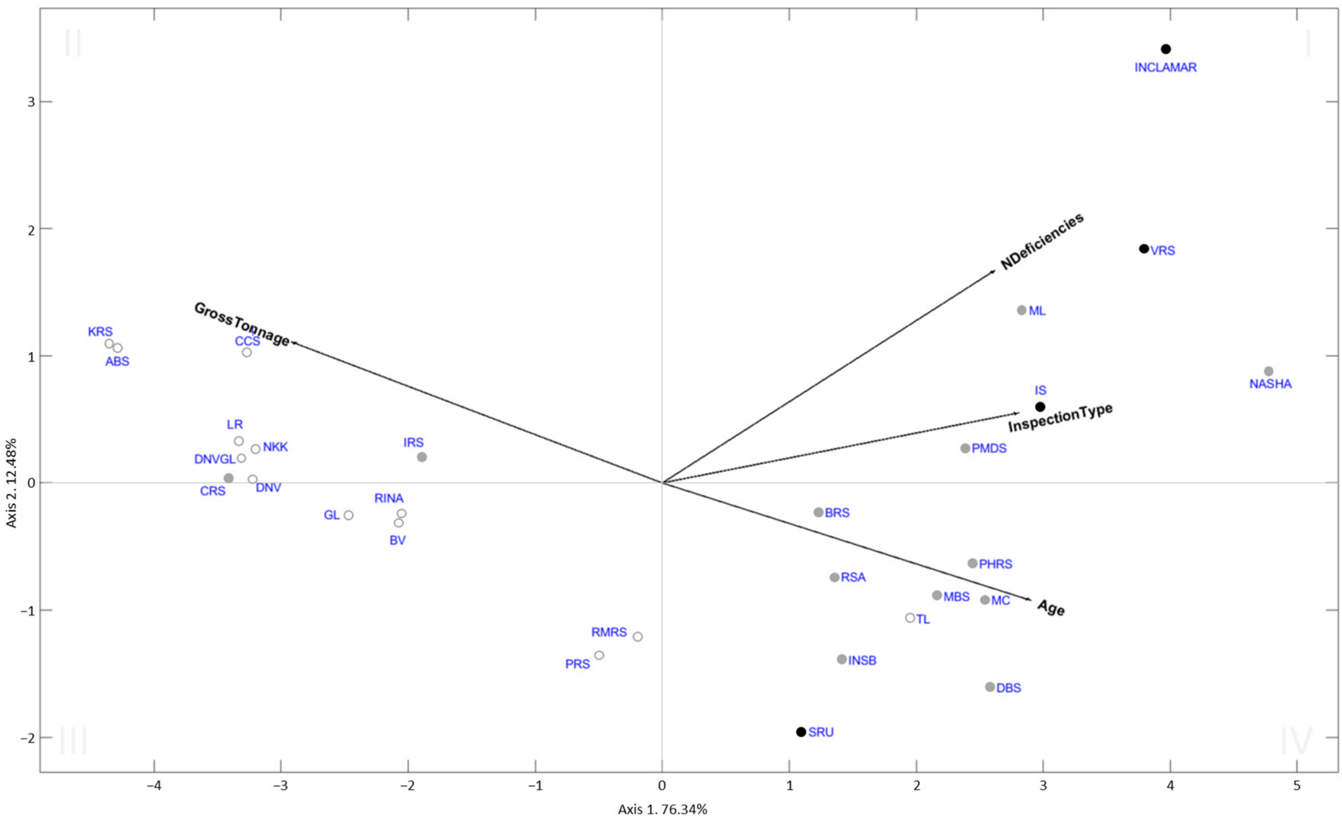

Figure 5. HJ-Biplot representation of classification societies.

The classification societies differ in terms of the variables examined. While the structure of the variables remains consistent with the previous sections, there is a more pronounced relationship between the type of inspection and the number of deficiencies in this context.

According to the variables observed in Table 10, the first quadrant is defined by the type of inspection and the number of deficiencies. Classification societies in this quadrant have a higher number of deficiencies and undergo more extensive inspections. In contrast, classification societies in the third quadrant have fewer deficiencies and are subject to less comprehensive inspections. Gross tonnage is in the second quadrant, suggesting that classification societies in this quadrant are associated with large, young ships. Conversely, the fourth quadrant is characterised by lower gross tonnage and older ships associated with the classification societies in that quadrant.

Figure 5 has grey, black, and white dots representing the corresponding performance list of the Paris MoU classification societies. White corresponds to a high-performance level, grey to a medium-performance level, and black to a low- to very-low-performance level.

This implies that ships affiliated with classification societies such as INCLAMAR, VRS, ML, IS, and NASHA tend to exhibit a higher number of deficiencies. Conversely, classification societies like CCS, ABS, KRS, LR, NKK, and DNVGL are linked to larger, more recent ships with fewer deficiencies. These findings are consistent with the annual performance list of classification societies published by the Paris MoU at all classification levels; the first group mentioned is typically listed in the Paris MoU's low- to very-low-performance category, while the second group tends to be listed in the high-performance category. The alignment of classification society positions with those in the Paris MoU performance lists [50] suggests the potential usefulness of this method as a classification tool. The list published in 2019 was also compared as a verification test, and the results are consistent with this study.

A subsequent verification exercise was carried out with the classification societies belonging to the International Association of Classification Societies (IACS), including ABS, BV, CCS, DNV, IR, KR, LR, NKK, PRS, RINA, and RS. To be a part of this international association, classification societies must guarantee professional integrity and maintain the high-quality standards required by IACS. This is achieved through an initial assessment and periodic verification of these standards, which are also verified by independent accredited certification bodies. All IACS [50] societies fall into the category with the lowest number of deficiencies, indicating an association with younger and larger ships.

3.5. Biplot Representation of the 10 Most Important Paris MoU Ports

Lastly, using the HJ-Biplot analysis, the 10 most important Paris MoU ports of the study period, from which the inspection data for this study were obtained, were projected onto the variables that evaluate the ship's dimensions, age, inspection type, and number of deficiencies found. This makes it possible to characterise each port and find the main differences among them.

Various measures are essential to apply and interpret the HJ-Biplot correctly, specifically, eigenvalues and explained variance (Table 11), and the relative contribution of the factor to the element (Table 12).

Table 11. Eigenvalues and explained and accumulated variance of Paris MoU Ports.

Axis	Eigenvalues	%Variance	%Accumulated
Axis 1	16.28	45.21	45.21
Axis 2	13.70	38.04	83.25
Axis 3	4.37	12.13	95.39
Axis 4	1.66	4.62	100.00

The first two axes of the analysis explain 83% of the data variability; therefore, the 1–2 factorial plane is used to represent the ports and variables (Figure 6).

Table 12. Relative contribution of each factor to each element of Paris MoU Ports.

Variable	Axis 1	Axis 2
GrossTonnage	459	321
Age	764	144
InspectionType	271	638
NDeficiencies	315	419

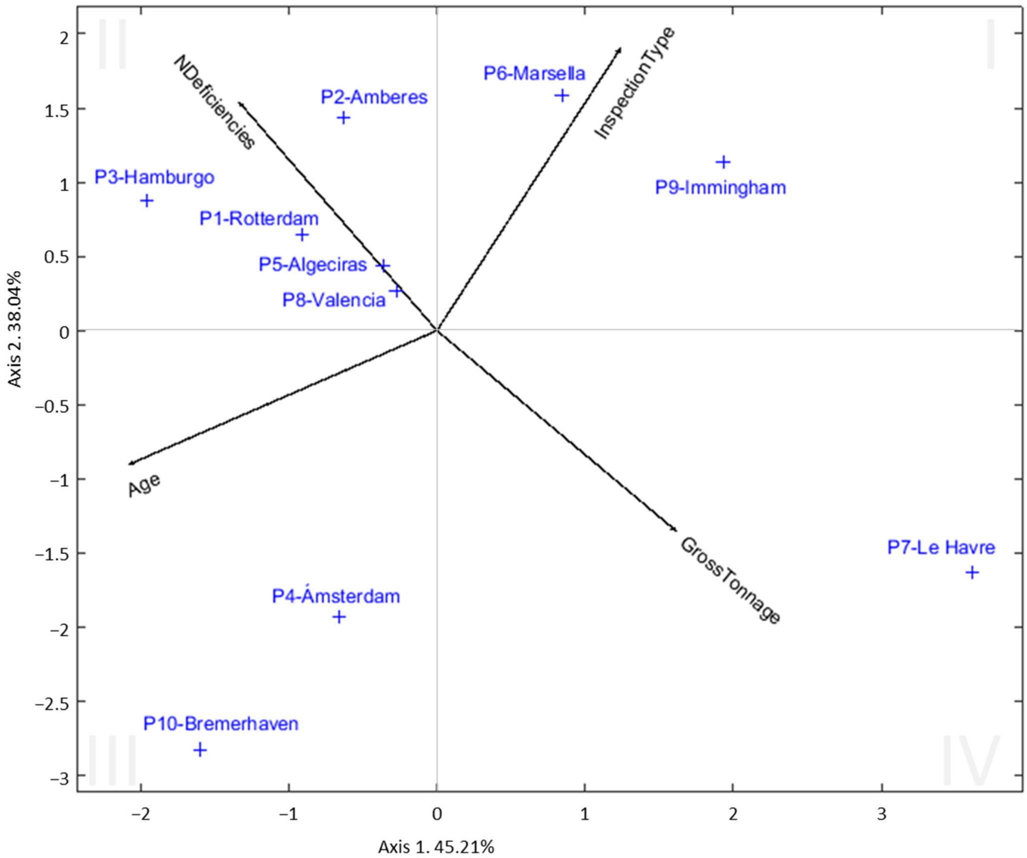

Figure 6. HJ-Biplot representation of the 10 most important Paris MoU ports.

In this representation, the relationship between variables is weaker than in previous sections; however, it is possible to characterise the ports based on these variables. The results show that the most exhaustive inspections are carried out in Marseille, Immingham, Antwerp, and Le Havre, whereas the least rigorous inspections occur in Amsterdam and Bremerhaven.

The ships with the highest number of deficiencies are found in Hamburg and Antwerp, whereas the opposite is found in Le Havre and Bremerhaven.

The port of Le Havre contains larger ships than the rest of the ports; the next in line are Amsterdam and Bremerhaven.

With respect to age, the oldest ships are found in Amsterdam, Bremerhaven, and Hamburg. It is important to note that although Amsterdam and Bremerhaven ports have old ships, the numbers of deficiencies found are low.

4. Conclusions

In this article, PSC inspections underwent analysis through an innovative methodology. This approach unveiled several trends within the variability in the selected variables, with the analysis centred on ten ports representing the primary ports in the Paris MoU region.

An expected conclusion was the heterogeneity in the maritime traffic inside the ports, in terms of ship type, gross tonnage, and behaviour towards the inspections.

Within the HJ-Biplot structure created by the quantitative variables, a distinct positive correlation is evident between ship age and the number of deficiencies, as well as between age and dimensions. Both associations describe the characteristics of a substandard ship profile as a small, old ship. This is one of the most important results obtained, as the identification of substandard ships is one of the main objectives of the NIR.

At the opposite end of the spectrum are larger vessels, consistent with the worldwide trend towards continually increasing ship sizes. Examples include container ships, tankers, and NLS tankers, which have witnessed a growth in both number and size over the past decade.

The HJ-Biplot diagram representing the country of registry reveals the existence of three clearly differentiated groups. Firstly, the countries in the right half of Figure 3 have newer vessels, larger gross tonnage, and fewer deficiencies and are included in the white list of the Paris Memorandum of Understanding, confirming the validity of this analysis. A second group consists of countries with older vessels, smaller gross tonnage, and a higher number of deficiencies, all of which are included in the grey list of the Paris MOU and occupy the left half of Figure 3. Finally, the countries on the black list of the Paris MoU occupy the left half of the graph and have the least favourable characteristics.

With respect to the biplot of the type of ships inspected, it was found that on the right are the more problematic ships with more deficiencies, such as refrigerated cargo ships, Ro-Ro passenger ships, and general multipurpose cargo ships; conversely, those on the left plane are less problematic ships with fewer deficiencies, such as NLS tankers, oil tankers, gas carriers, and container ships. In the intermediate area is the bulk carrier, which, although it is a larger type of vessel, also tends to have a large number of deficiencies.

The examination of various classification societies identified during PSC inspections reveals their categorisation into distinct groups. Specifically, ships exhibiting a higher number of deficiencies align with a specific set of classification societies (GMB, INCLAMAR, VRS, ML, IS, or NASHA). On the contrary, a distinct cluster (CCRS, CCS, ABS, KRS, LR, NKK, or DNVGL) within the International Association of Classification Societies (IACS) [50] is associated with larger, newer ships characterised by a lower incidence of deficiencies. This correspondence with the results of the annual Paris MoU Performance Lists confirms the validity of the proposed classification method.

This method's novelty lies in the way it distinguishes inspection practices. There is a disparity between ports with some conducting exhaustive inspections (like, for instance, Marseille, Immingham, Antwerp, and Le Havre) and others conducting a lot fewer (such as Amsterdam and Bremerhaven). There are also different groups of ports with inspection results that vary noticeably in the number of deficiencies found (higher number of substandard vessels, higher number of deficiencies, and older vessels in ports like Hamburg and Antwerp, as opposed to Le Havre and Bremerhaven). The other variables studied generate groups of ports including ship dimensions (in Le Havre port ships are larger, followed by Amsterdam and Bremerhaven) and ship age (the oldest are found in Hamburg, Amsterdam, and Bremerhaven).

In conclusion, the application of this multivariate methodology to PSC inspections contributes to the classification of flag and classification society performance. The applied method is mainly used to explore and understand the structure of the data, providing a visual representation that facilitates the interpretation and understanding of the underlying relationships in a multivariate data set. The results are shown in a single image represented by a factorial plane that synthesises the information and can be interpreted in a very intuitive way, i.e., in a language accessible to readers from various fields. Consequently, it could be used as a complementary indicator to ship risk profiles to assist in the setting of inspection priorities. Similarly, the method has been used to establish classifications based on ship type and port, facilitating the analysis of traffic in recent years within the Paris MoU area.

This study shows that there are several easily implementable techniques within the field of multivariate analysis that can improve maritime safety and prevent marine pollution. In relation to the limitations of this article that should be taken into account in future research, it should be noted that the method used is not used to make formal statistical inferences, and other methods could be used that add greater value to the results by performing inference. For example, bootstrap resampling can be applied to this type of data or other methods that give greater priority to the third dimension and can show trends over time. These methods can be used as a tool to measure the evolution in the risk profile of the flag over time.

Author Contributions: Conceptualisation, F.P. and D.A.; methodology, D.A. and V.A.-E.; software, V.A.-E. and J.M.P.; validation, F.P. and D.A.; formal analysis, D.A. and V.A.-E.; investigation, J.M.P.; resources, F.P. and J.M.P.; data curation, V.A.-E.; writing—original draft preparation, J.M.P., V.A.-E. and D.A.; writing—review and editing, J.M.P., V.A.-E. and D.A.; visualisation, F.P. and J.M.P.; supervision, F.P. and D.A.; project administration, F.P. and D.A.; funding acquisition, D.A. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by University of Cádiz.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Paris Memorandum of Understanding (Paris MoU), https://parismou.org/Statistics&Current-Lists/white-grey-and-black-list (accessed on 16 December 2023); European Maritime Safety Agency (EMSA), https://portal.emsa.europa.eu/web/thetis (accessed on 10 October 2023); Eurostat, https://ec.europa.eu/eurostat/web/main/data/database (accessed on 10 December 2023).

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Piniella, F.; Alcaide, J.I.; Rodríguez-Díaz, E. The Panama Ship Registry: 1917–2017. *Mar. Policy* **2017**, *77*, 13–22. [CrossRef]
2. Piniella, F.; Alcaide, J.I.; Rodríguez-Díaz, E. Identifying Stakeholder Perceptions and Realities of Paris MoU Inspections. *WMU J. Marit. Aff.* **2020**, *19*, 27–49. [CrossRef]
3. Wang, S.; Yan, R.; Qu, X. Development of a Non-Parametric Classifier: Effective Identification, Algorithm, and Applications in Port State Control for Maritime Transportation. *Transp. Res. Part B Methodol.* **2019**, *128*, 129–157. [CrossRef]
4. Li, K.X.; Zheng, H. Enforcement of Law by the Port State Control (PSC). *Marit. Policy Manag.* **2008**, *35*, 61–71. [CrossRef]
5. International Maritime Organization. *Port State Control (Model Course 3.09)*; 2001; ISBN 9280151045.
6. International Maritime Organization. *Procedures for Port State Control, 2011 (Resolution A.1052(27)*; 2011. Available online: https://wwwcdn.imo.org/localresources/en/KnowledgeCentre/IndexofIMOResolutions/AssemblyDocuments/A.1052(27).pdf (accessed on 5 May 2023).
7. International Maritime Organization. *Amendments to the Procedures for Port State Control (Resolution A.787(19)*; 2012. Available online: https://wwwcdn.imo.org/localresources/en/KnowledgeCentre/IndexofIMOResolutions/AssemblyDocuments/A.1052(27).pdf (accessed on 5 May 2023).
8. Knapp, S.; Franses, P.H. A Global View on Port State Control: Econometric Analysis of the Differences across Port State Control Regimes. *Marit. Policy Manag.* **2007**, *34*, 453–482. [CrossRef]
9. International Maritime Organization. *Procedures for Port State Control*; 2019; ISBN 978-92-801-1698-4. Available online: https://wwwcdn.imo.org/localresources/en/publications/Documents/Flyers/Flyers/ID650E.pdf (accessed on 5 May 2023).
10. European Maritime Safety Agency (EMSA), THETIS. Available online: https://portal.emsa.europa.eu/web/thetis (accessed on 5 May 2023).
11. Brooks, M.R. The Privatization of Ship Safety. *Marit. Policy Manag.* **1996**, *23*, 271–288. [CrossRef]
12. Havold, J.I. Culture in Maritime Safety. *Marit. Policy Manag.* **2000**, *27*, 79–88. [CrossRef]
13. Knapp, S. Analysis of the Maritime Safety Regime: "Risk Improvement Possibilities for the Port State Control Target Factor" (Paris MoU). In *Thesis in Maritime Economics and Logistics*; Erasmus University Rotterdam: Rotterdam, The Netherlands, 2004; p. 123.
14. Knapp, S.; Franses, P.H. Econometric Analysis on the Effect of Port State Control Inspections on the Probability of Casualty. *Mar. Policy* **2007**, *31*, 550–563. [CrossRef]
15. Knapp, S.; van de Velden, M. Visualization of Differences in Treatment of Safety Inspections across Port State Control Regimes: A Case for Increased Harmonization Efforts. *Transp. Rev.* **2009**, *29*, 499–514. [CrossRef]
16. Bijwaard, G.E.; Knapp, S. Analysis of Ship Life Cycles—The Impact of Economic Cycles and Ship Inspections. *Mar. Policy* **2009**, *33*, 350–369. [CrossRef]

17. Knapp, S.; Franses, P.H. Comprehensive Review of the Maritime Safety Regimes: Present Status and Recommendations for Improvements. *Transp. Rev.* **2010**, *30*, 241–270. [CrossRef]
18. Bang, H.-S.; Jang, D.-J. Recent Developments in Regional Memorandums of Understanding on Port State Control. *Ocean Dev. Int. Law* **2012**, *43*, 170–187. [CrossRef]
19. Li, K.X.; Yin, J.; Fan, L. Ship Safety Index. *Transp. Res. Part A Policy Pract.* **2014**, *66*, 75–87. [CrossRef]
20. Ozcayr, Z.O. The Use of Port State Control in Maritime Industry and Application of the Paris MoU. *Ocean Coast. LJ* **2008**, *14*, 201.
21. Wu, J.; Jin, Y.; Fu, J. Effectiveness Evaluation on Fire Drills for Emergency and PSC Inspections on Board. *TransNav Int. J. Mar. Navig. Saf. Sea Transp.* **2014**, *8*, 229–236. [CrossRef]
22. Ravira, F.J.; Piniella, F. Evaluating the Impact of PSC Inspectors' Professional Profile: A Case Study of the Spanish Maritime Administration. *WMU J. Marit. Aff.* **2016**, *15*, 221–236. [CrossRef]
23. Graziano, A.; Cariou, P.; Wolff, F.-C.; Mejia, M.Q.; Schröder-Hinrichs, J.-U. Port State Control Inspections in the European Union: Do Inspector's Number and Background Matter? *Mar. Policy* **2018**, *88*, 230–241. [CrossRef]
24. EU Directive2009/16/EU, of the European Parliament and of the Council, of the 23rd April, on the Control of Ships by the Port State Control Amended by Directive 2013/38/EU. Available online: https://transport.ec.europa.eu/system/files/2023-06/COM_2023_271_Port_State_Control.pdf (accessed on 23 May 2023).
25. Chen, J.; Zhang, S.; Xu, L.; Wan, Z.; Fei, Y.; Zheng, T. Identification of Key Factors of Ship Detention under Port State Control. *Mar. Policy* **2019**, *102*, 21–27. [CrossRef]
26. Knapp, S.; Heij, C. Improved Strategies for the Maritime Industry to Target Vessels for Inspection and to Select Inspection Priority Areas. *Safety* **2020**, *6*, 18. [CrossRef]
27. Wang, Y.; Zhang, F.; Yang, Z.; Yang, Z. Incorporation of Deficiency Data into the Analysis of the Dependency and Interdependency among the Risk Factors Influencing Port State Control Inspection. *Reliab. Eng. Syst. Saf.* **2021**, *206*, 107277. [CrossRef]
28. Prieto, J.M.; Amor, V.; Turias, I.; Almorza, D.; Piniella, F. Evaluation of Paris Mou Maritime Inspections Using a Statis Approach. *Mathematics* **2021**, *9*, 2092. [CrossRef]
29. Liu, K.; Yu, Q.; Yang, Z.; Wan, C.; Yang, Z. BN-Based Port State Control Inspection for Paris MoU: New Risk Factors and Probability Training Using Big Data. *Reliab. Eng. Syst. Saf.* **2022**, *224*, 108530. [CrossRef]
30. Lai, C.Y.; Liu, C.P.; Huang, K.M. Optimization of the Concentrated Inspection Campaign Model to Strengthen Port State Control. *J. Mar. Sci. Eng.* **2023**, *11*, 1166. [CrossRef]
31. Xiao, G.; Wang, T.; Luo, Y.; Yang, D. Analysis of Port Pollutant Emission Characteristics in United States Based on Multiscale Geographically Weighted Regression. *Front. Mar. Sci.* **2023**, *10*, 1131948. [CrossRef]
32. Liu, Z.; Gao, H.; Zhang, M.; Yan, R.; Liu, J. A Data Mining Method to Extract Traffic Network for Maritime Transport Management. *Ocean Coast. Manag.* **2023**, *239*, 106622. [CrossRef]
33. Chen, X.; Liu, S.; Liu, R.W.; Wu, H.; Han, B.; Zhao, J. Quantifying Arctic Oil Spilling Event Risk by Integrating an Analytic Network Process and a Fuzzy Comprehensive Evaluation Model. *Ocean Coast. Manag.* **2022**, *228*, 106326. [CrossRef]
34. Yazir, D.; Şahin, B.; Yip, T.L.; Tseng, P.-H. Effects of COVID-19 on Maritime Industry: A Review. *Int. Marit. Health* **2020**, *71*, 253–264. [CrossRef] [PubMed]
35. Prieto, J.M.; Amor-Esteban, V.; Almorza-Gomar, D.; Turias, I.; Piniella, F. Application of Multivariate Statistical Techniques as an Indicator of Variability of the Effects of COVID-19 on the Paris Memorandum of Understanding on Port State Control. *Mathematics* **2023**, *11*, 3188. [CrossRef]
36. Eurostat. Database. Maritime Transport of Goods. Available online: https://ec.europa.eu/eurostat/web/transport/data/database (accessed on 16 May 2023).
37. Gabriel, K.R. The Biplot Graphic Display of Matrices with Application to Principal Component Analysis. *Biometrika* **1971**, *58*, 453–467. [CrossRef]
38. Villardón, M.P.G. Una Alternativa de Representación Simultánea: HJ-Biplot. *Qüestiió Quad. D'estadística I Investig. Oper.* **1986**, *10*, 13–23.
39. Orfao, A.; Gonzalez, M.; Miguel, J.S.; Rios, A.; Caballero, M.D.; Sanz, M.; Calmuntia, M.J.; Galindo, P.; Borrasca, A.L. Bone Marrow Histopathologic Patterns and Immunologic Phenotype in B-Cell Chronic Lymphocytic Leukaemia. *Blut Z. Für Die Gesamte Blutforsch* **1988**, *57*, 19–23. [CrossRef]
40. Rivas-Gonzalo, J.; Gutiérrez, V.; Polanco, A.; Hebrero, E.; Vicente Villardon, J.L.; Galindo Villardón, M.-P.; Santos, C. Biplot Analysis Applied to Enological Parameters in the Geographical Classification of Young Red Wines. *Am. J. Enol. Vitic.* **1993**, *44*, 302–308. [CrossRef]
41. Mendes, S.; Fernández-Gómez, M.J.; Galindo Villardón, M.P.; Morgado, F.; Maranhão, P.; Azeiteiro, U.; Bacelar-Nicolau, P. The Study of Bacterioplankton Dynamics in the Berlengas Archipelago (West Coast of Portugal) by Applying the HJ-Biplot Method. *Arquipélago Life Mar. Sci.* **2009**, *26*, 25–35.
42. Viloria, J.; Gil, J.; Durango, D.; García, C. Physiochemical Characterization of Propolis from the Region of Bajo Cauca Antioqueño (Antioquia, Colombia). *Biotecnol. En El Sect. Agropecu. Y Agroindustrial* **2012**, *10*, 77–86.
43. Díaz-Faes, A.A.; González-Albo, B.; Galindo, M.P.; Bordons, M. HJ-Biplot Como Herramienta de Inspección de Matrices de Datos Bibliométricos. *Rev. Esp. Doc. Cient.* **2013**, *36*, e001. [CrossRef]
44. Sánchez, I.; Frias-Aceituno, J.-V.; Rodríguez-Domínguez, L. Determinants of Corporate Social Disclosure in Spanish Local Governments. *J. Clean. Prod.* **2013**, *39*, 60–72. [CrossRef]

45. Gallego-Álvarez, I.; Galindo-Villardón, M.P.; Rodríguez-Rosa, M. Analysis of the Sustainable Society Index Worldwide: A Study from the Biplot Perspective. *Soc. Indic. Res.* **2015**, *120*, 29–65. [CrossRef]
46. Amor-Esteban, V.; Sánchez, I.; Galindo Villardón, M.P. Analysing the Effect of Legal System on Corporate Social Responsibility (CSR) at the Country Level, from a Multivariate Perspective. *Soc. Indic. Res.* **2018**, *140*, 435–452. [CrossRef]
47. Amor-Esteban, V.; Galindo-Villardón, M.-P.; García-Sánchez, I.-M. Industry Mimetic Isomorphism and Sustainable Development Based on the X-STATIS and HJ-Biplot Methods. *Environ. Sci. Pollut. Res.* **2018**, *25*, 26192–26208. [CrossRef]
48. Vicente-Villardón, J.L. MULTBIPLOT: A Package for Multivariate Analysis Using Biplots. Departamento de Estadística. Universidad de Salamanca. 2010. Available online: http://biplot.dep.usal.es/multbiplot/ (accessed on 5 May 2023).
49. Paris MoU Performance Lists. Available online: https://parismou.org/Statistics&Current-Lists/white-grey-and-black-list (accessed on 16 November 2023).
50. IACS Safer and Cleaner Shipping—IACS. Available online: https://iacs.org.uk/ (accessed on 12 April 2023).