International Core Journal of Engineering Volume 8 Issue 3, 2022
ISSN: 2414-1895 DOI: 10.6919/ICJE.202203_8(3).0051

Analysis of Ship Detention Defect in PSC Inspection based on Generalized Linear Model

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Abstract

The more the number of detention defects is, the more hidden dangers of safety and pollution prevention are, and the higher the corresponding detention rate is, which is worthy of attention of shipping companies. The number of detention defects of ships directly reflects the safety status and risk level of different types of ships. This paper studies the relationship between ship inherent attributes (ship age, ship tonnage, flag country, classification society), port country inspection items (ship recognized organization performance list, flag country performance list) and the number of ship retention defects. The data used in this paper are mainly from the Tokyo MOU database, a total of 4359 detained ships. The Poisson regression model, zero-tailed Poisson regression model and zero-tailed negative binomial regression model are used by using the common models of count data. At the same time, the model is evaluated by using the value of the pseudo-log likelihood function (Log pseudo likelihood), the red pool information criterion (AIC) and the Bayesian information criterion (BIC). The results show that the inherent attributes of the ship and the performance level of the port state inspection items have a high direct impact on the number of ship detention defects, and the effect is also slightly different for ships of different types.

Keywords

Port State Control; Detainable Deficiencies; Maritime Safety; Tokyo MOU.

1. Introduction

Port State control (PSC) is a special inspection system for foreign ships arriving at ports implemented by port State authorities around the world. The main purpose of PSC inspection is to ensure the safety of ships and personnel and prevent ships from polluting the marine environment. At the same time, the inspection target is the operation status of crew and ships. In addition, PSC maritime authorities should examine the situation of flag countries and supplement the deficiencies of the regulations. PSC inspection is an important measure to ensure that ships meet the requirements of relevant international conventions and the last important defense line for maritime safety[1].Non-standard ships that do not conform to international maritime rules are the objectives of port state control inspection. However, due to the high cost of inspection, many inspections have not led to any detention, and in many cases no defects have been found. Therefore, in order to strengthen the efficiency of ship safety management, it is necessary to quantitatively study the relationship between the number of detention defects in the monitoring and inspection of the port state of the ship and the influencing factors.

1.1 Ship Detention Factors

As an important means of supervision of ships arriving in port countries, port state control greatly ensures the safe navigation of ships and prevents ships from polluting the marine environment. The detention defects found in the port state inspection reflect the overall safety of the ship[2].Combined

ISSN: 2414-1895 DOI: 10.6919/ICJE.202203_8(3).0051

with previous studies, the factors affecting ship retention in PSC inspection are generally: ship age, ship type, flag state, ship tonnage, ship rating organization, etc. In essence, the physical properties of the ship determine that there may be some defects in the ship, and these defects on the other hand intuitively show the safety of the ship[3].The defects found in PSC inspection reflect the overall safety situation of the ship. The more the defects are, the more hidden dangers of safety and pollution prevention are, so the safety situation of the ship can be reflected according to the number of detention defects.

2. Literature References

2.1 Overview of the Legal Framework of Port State Control Regimes

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

1) Europe and North Atlantic (Paris MoU).

2) Asia and the Pacific (Tokyo MoU).

3) Latin America (Acuerdo de Vin˜ a del Mar).

4) Caribbean (Caribbean MoU).

5) West and Central Africa (Abuja MoU).

6) Black Sea (Black Sea MoU).

7) Mediterranean (Mediterranean MoU).

8) Indian Ocean (Indian Ocean MoU).

9) Arab States of the Gulf (Riyadh MoU).

10) US (US Coast Guard).

The first port state control regime was the Paris Memorandum of Understanding (Paris MoU) in 1982 [4]followed by the others listed previously and noting the standards listed in IMO Resolution A.682 (17) [5] calling for regional cooperation in ships inspections while Resolution A 787 (19) with its amendment of A 822(21) provides guidelines on the procedures to conduct port state control inspections. The regimes were compared based on their legal relevant instruments for inspection on foreign vessels, their targeting system and the inspection systems including the deficiency coding and detentions [6].

2.2 Overview of PSC Inspection

There are many ways for ship safety management, such as flag State, port State, industry organization and so on. The improvement of ship safety management level helps to reduce ship accidents and marine pollution[7]. PSC inspection results are the external manifestation of the ship safety management in flag countries. Although there are a large number of studies on inspection and ship safety management in China and abroad, there is little consideration of the relationship between the number of trapped ships and the number of defects under the supervision of port countries.

The 27 maritime administrations in the Paris Memorandum of Understanding on Port State Supervision considered 10 criteria for dividing vessels into low, medium or high-risk vessels : vessel type (6 types), vessel age (more than 12 years or less), flag State performance (appearing on the black-grey-white list), whether the International Maritime Organization had not tried sailing before, recognized organizational performance, ISM (International Security Management) company performance, the number of inspections or non-inspections in the past 36 months, the number of defects detected (more than or less than 5) and the number of detentions in the past. The specific weight of each standard is different, and countries generally have their own focus. Port State Supervision (PSC) determines the priority of ship PSC inspection by using various common parameters and historical parameters to classify ships with high risk, standard risk or low risk. Esad Demirci et al. proposed a new ship risk profile (SRP) prediction model based on fuzzy clustering

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analysis (FCA) and fuzzy rule classification system (FRBS). The model is based on five parameters: ship type, flag state, ship age, defect number and retention[8]. Chen J et al. used the improved entropy weight grey rational analysis (GRA) model to analyze the influencing factors of ship retention under PSC, in order to understand the influence degree of various factors on ship retention decision and find out the key factors affecting ship retention.[9] Anler E analysed ship defects identified in the 29954 PSC inspection conducted in the Black Sea Memorandum area between 2012 and 2017. The main reason of 1325 detention cases is the age of the ship. At the same time, factors such as ship type, ship registration mark, recognized organization and inspection authorities are very effective in detention. Another important finding of this study is that there are differences between the inspections of port countries because the authorities of the member countries of the memorandum have their own methods [10].

For the flag state factor in the ship selection system, both Tokyo and Paris memorandums adopt the “ blacklist system ” to measure the risk factors of flag states.Cariou P et al. found speculation among shipowners : ships detained or with many defects seemed more likely to change their registration or classification flag to avoid future inspections[11].

M. Perepelkin et al. proposed a new flag State performance assessment methodology to address PSC inspections[12].

J. Chen et al. considered flag selection an important decision of shipping companies. Scholars have proposed different considerations and methods for such decision modeling[13].

For the age factor in the ship selection system, Knapps et al. conducted a detailed analysis of the inspection records over the past six years (about 18,000 inspections). The main conclusion is that ship age is the most important factor to predict ship quality so far. Ship types, ship inspection history and, in some cases, ship size also appear to have a significant impact[14].

Fan et al. (2014) integrated the binary logit model for marking decision and the linear model for explaining PSC inspection rate. The results show that PSC inspection actually increases the possibility of flag State exit, not only because of the high inspection rate, but also by setting the variables used in the inspection priority, such as ship age[15]. Although age is not the only factor, Cariou P et al. confirmed the importance of age from the inspection data of the Swedish Maritime Authority and the Indian Ocean Memorandum of Understanding[16]. The Australian Federal Organization for Scientific and Industrial Research (CSIRO) Department of Mathematics and Information Science (2014) carried out a detailed analysis of the inspection records. The main conclusion is that ship age is the most important fact to predict ship quality so far. Ship type, ship inspection history and, in some cases, ship size also appear to have a significant impact on ship safety[17] . X. Ji, J. Brinkhuis and others found it more challenging to oversee an old fleet engaged in local trade than a young tanker fleet and, in the same inspection context, the average retention rate for the old fleet would be higher [18].

3. Method and Processing

3.1 Methods

Table 1. TOKYO MOU PSC data statistics

Year	Num of inspections	Num of detention	Detention rate	Num of defects
2016	31678	1090	3.44%	81271
2017	31315	941	3.00%	76108
2018	31589	934	2.96%	73441
2019	31372	983	3.13%	73393
2020	19415	493	2.54%	34924

ISSN: 2414-1895 DOI: 10.6919/ICJE.202203_8(3).0051

This paper takes the number of stranded defects as an explanatory variable and selects 4359 stranded ship data from Tokyo MOU from January 2016 to October 2020, see Table 1. Combined with previous studies, from two angles to analyze the factors affecting the number of ship retention defects, one is the inherent properties of the ship, including : ship age, ship tonnage, flag country, classification society, whether belong to the flag of convenience ; second, port state inspection items: ship recognized organization performance list, flag state performance list. The number of stranded defects of each ship type on the list is fitted by counting data model.

Firstly, the correlation analysis of the number of detention defects shows that there is no multicollinearity among the influencing factors of the number of detention defects of the detained ship selected in this paper. Secondly, under the premise of considering the over-discrete characteristics of the data, it is assumed that the distribution of the number of detention defects of different ship types is Poisson distribution or negative binomial distribution, and the parameters of the distribution are assumed to be random to consider the uncertainties and correlation characteristics from various aspects.

In this paper, the regression of count data can be used to estimate the number of known ship detention defects, and its purpose is to supplement the existing practice focusing on detention, so as to improve the selection process. The application of zero truncated Poisson distribution regression helps to identify the number of retention defects through specific factors, which can also provide some help for the Centralized Inspection Movement (CIC).

3.2 Factors

3.2.1 Flags

In order to better quantify the effect of flags, we think it is best to distinguish ship types. The classification of ship types refer to Pierre Cariou[19],mainly using the following five types: 1) grocery ship, 2) dry bulk carrier, 3) container ship, 4) tanker, 5) passenger ship and 6) all other ship types. For other reasons, ship type can also be used to measure other factors such as age and size. The ship classification results are shown in Figure 1.

Ship type	Age Mean	GRT Mean	Deficiencies Mean	Detention rate	Incident rate (very serious)
General cargo	18.7	9,326	4.08	7.0%	0.0031
Dry bulk carriers	14.4	31,462	2.82	4.0%	0.0021
Container ships	9.7	33,885	1.79	1.8%	0.0020
Tankers	10.1	29,959	1.85	2.3%	0.0009
Passenger ships	18.9	33,626	3.00	2.4%	0.0020
Other ship types	20.8	4,315	3.96	8.1%	0.0099

Figure 1. Graph of ship classification results

3.2.2 Vessel Age

According to the list of stranded ships provided by the Tokyo Memorandum of Understanding for 2016-2020, the age of stranded ships is mainly concentrated in 10-20 years, accounting for about 70 per cent of the total number of stranded ships. According to statistics, in port State supervision and inspection, the number of detention defects of ships aged over 40 years is the largest, and the number of detention defects of ships aged 0-5 years is also higher than that of ships aged 5-10 years, see figure 2.

It can be seen that the number of ship stranded defects is closely related to ship age. The ship with larger ship age is generally poor and has more security risks. Therefore, the inspector (PSCO) will also focus on the ship with larger ship age, and the more the stranded defects are, so the ship age is one of the reasons that affect the number of ship stranded defects.

Volume 8 Issue 3, 2022
DOI: 10.6919/ICJE.202203_8(3).0051

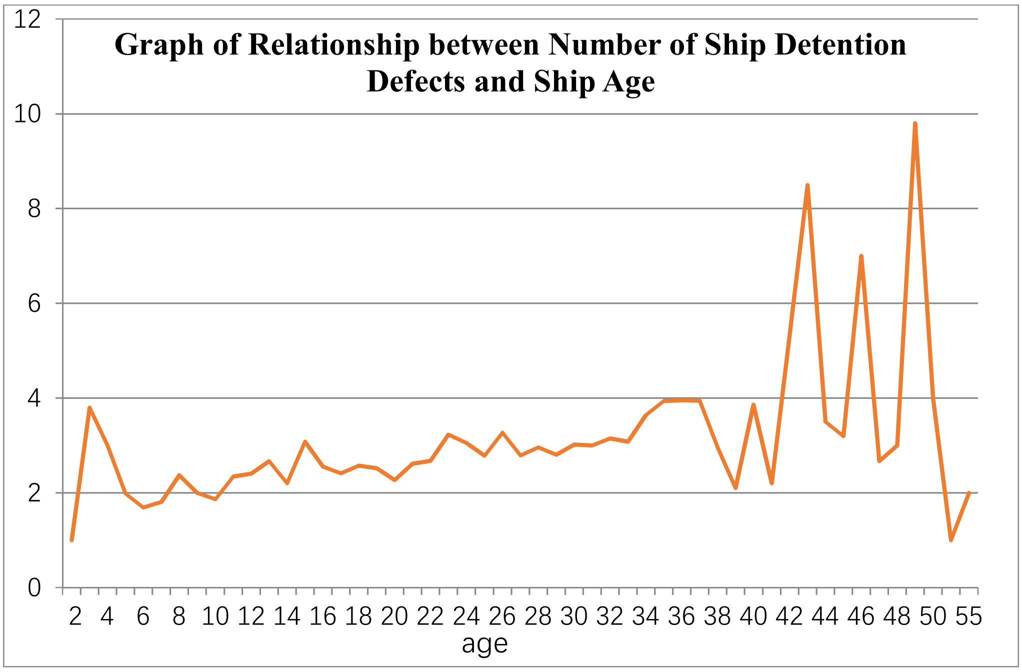

Figure 2. Graph of Relationship between Numbers of Ship Retention Defects and Ship Age

3.2.3 Ship Tonnage

When analyzing the relationship between ship retention risk and ship, the size of the ship is usually taken as an important factor in the analysis. The ship size is usually considered mainly from the two aspects of the master and the total tonnage. However, in fact, the master and the tonnage are the same manifestations of the ship size in different aspects. The larger the ship length is, the larger the total tonnage of the ship will be. Therefore, it is feasible to use the total tonnage as the measurement factor of the ship size when analyzing the influence of the ship size on the amount of ship retention defects. The table shows that the maximum number of tonnage retention is 10000-50000t, but the maximum number of retention defects is 500-3000t, see Table 2.

Table 2. TOKYO MOU PSC ship tonnage data statistics

gross	mean	variance	N
0-500	2.856	5.586	90
500-3000	3.284	8.143	1016
3000-10000	2.966	5.431	949
10000-50000	2.301	2.893	1697
50000-100000	1.754	1.249	488
100000-	1.788	1.245	118

3.2.4 White-gray-black List

From high-performance flag States to low-performance flag States, the white-gray-black list covers all areas. Flag country performance is calculated based on the number of inspections and detentions in the past three years, and at least 30 inspections are required. Since July 1, 2018, the White Grey List and Black List has been used to calculate the risk attributes of ships. There are 73 flags in the list, including 40 white flags, 20 grey flags and 13 black flags. In 2017, the white-grey-black list also included 73 flags, 42, 19 and 12, respectively.

The grey list means that the performance of flag states is average, and their presence on this list may encourage them to improve and transfer to the white list. At the same time, flag States under the grey list should note that control of their ships should not be ignored to prevent the risk of entering the blacklist next year.

3.2.5 Flag State

According to the provisions of the United Nations Convention on the Law of the Sea, each country, whether coastal or landlocked, has the right to sail ships flying its flag on the high seas. Each country should determine the conditions for granting the nationality of the ship, registering the ship in its territory and flying the flag of the ship. The ship has the nationality of the flag State on which it is flying, and there must also be a genuine link between the State and the ship. Each State shall issue a document granting nationality to a ship flying its flag. In brief, the flag State refers to the country where the flag is attached to the stern, that is, the country where the ship is registered and granted the nationality of the ship. However, not all flag States in the world will implement the relevant standards of international conventions with the same degree of vigilance. Some countries lack the resources and capacity to implement the relevant international conventions, while others lack the will to fulfill the flag State obligations. Especially in some flag-convenience countries, the safety of vessels flying their flag is worrying.

4. Conclusion

The correlation analysis on the ship deficiencies from the PSC inspection dataset provides crucial ship inspection guidelines, which can identify the potential maritime traffic risking factors and significantly improve maritime safety. we have conducted a comprehensive ship deficiency correlation analysis by deeply diving into the PSC inspection dataset (i.e., focused on the ship type, age, deadweight and gross tonnage). The ship recognized organization performance list, flag country performance list were introduced to quantitatively analyze the ship deficiency correlations. The experimental results indicate that the ship type, age, deadweight and gross tonnage are closely related to the ship deficiency identification, which is particularly obvious in the ship detention incidents.

In linear regression analysis, there may be a linear correlation between independent variables, resulting in unreasonable parameter estimation or distortion of model estimation. In order to detect multicollinearity, this paper uses the variance inflation factor (VIF) test in regression analysis. According to the variance expansion factors (VIFs) to determine whether there is a multicollinearity threat, the greater the VIF value, the more serious the multicollinearity. It is generally believed that when VIF is greater than 5, there is a serious collinearity problem in the representative model. The results show that the VIFs are less than 1.35, so it can be considered that there is no multicollinearity between the independent variables selected in this paper.If you follow the “checklist” your paper will conform to the requirements of the publisher and facilitate a problem-free publication process.

Taking refrigerated ship as an example,see Table 3. Poisson regression model, negative binomial regression model and zero-tailed Poisson regression are used to analyze the data of refrigerated ship. Although the pseudo R2 of the three models are slightly small, except RO performance, other factors have a significant impact on the number of retention defects.

In the three models, the regression coefficients are -0.955, -0.949 and -1.122 when the ship age is between 20 and 25, respectively, indicating that the age level of the ship has a negative impact on the retention of bulk carriers. The greater the ship age, the less the number of retention defects; the simulated regression coefficients of ship tonnage in the three models are significantly positive, especially when the ship tonnage is 500 t-3000 t, the regression coefficients are 0.719, 0.747 and 0.839, respectively. Therefore, the ship tonnage has a positive impact on the number of retention defects, that is, when the ship tonnage is between 500 t and 3000 t, the greater the tonnage, the more the number of retention defects ; different from the regression results of other ship types, whether the flag of the refrigerated ship belongs to the flag State of convenience has no effect on the number of retention defects, and the black list of the flag State does not have a significant impact on the number of defects. Classification societies have a positive impact on the number of retention defects, with regression coefficients of 0.601, 0.587 and 0.703, respectively.

ISSN: 2414-1895 DOI: 10.6919/ICJE.202203_8(3).0051

Table 3. TOKYO MOU PSC ship tonnage data statistics

variable	poisson	NB	ZTP
vessel age	-0.955** (0.387)	-0.949** (0.384)	-1.122*** (0.420)
500t-3000t	0.719*** (0.220)	0.747*** (0.210)	0.839*** (0.284)
3000t-10000t	0.476* (0.256)	0.490** (0.245)	0.555* (0.324)
10000t-50000t	0.148 (0.265)	0.151 (0.261)	0.073 (0.392)
flag-on-convenience vessel	-0.073 (0.137)	-0.080 0.132	-0.098 (0177)
classification society	0.601*** (0.180)	0.587*** (0.168)	0.703*** (0.212)
High performance RO	0.291** (0.143)	0.317** (0.139)	0.337** (0.170)
Medium performance RO	0.385* (0.211)	0.379* (0.201)	0.405* (0.234)
Low performance RO	-	-	-
white lists	0.401 (0.275)	0.368 (0.262)	0.461 (0.346)
grey lists	0.673* (0.391)	0.629* (0.373)	0.759* (0.443)
blacklist	0.375 (0.255)	0.380 (0.247)	0.451 (0.319)
AIC	648.8603	636.7543	627.3477
BIC	705.5488	696.4264	684.0362
Log pseudo likelihood	-305.43015	-298.37714	-294.67386
Wald chi2	95.75***	98.04***	86.15***
Pseudo R2	0.147	0.097	0.169

Whether the ship stays or not is highly correlated with the number of defects and the specific types of defects. Based on this situation, this paper extends the classical Poisson distribution and introduces two types of zero-truncate distribution (ZTP) and zero-truncate negative binomial distribution (ZTNB). In predicting the number of detected defects or the possibility of a ship being detained, it has been shown to be an important factor in the age of the ship under inspection, the records of previous inspections, classification societies and ship types.

In many cases, we do not care about zero data or event does not occur. The number of detention defects may be related to the repair level and even the management level after the ship accident, which does not appear in the model, because the number of defects in the new inspection mechanism has a greater impact on the two weighted parameters of risk value and corporate performance.

ISSN: 2414-1895
DOI: 10.6919/ICJE.202203_8(3).0051

Acknowledgments

Natural Science Foundation.

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