Ship Inspection by Port State Control – Review of Current Research

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Abstract

Port state control (PSC) is an international regime to inspect the foreign ships coming to the port state in order to ensure that they are compliant with various international conventions. In this study, we conduct a review of the literature related to the PSC inspection in four areas: factors influencing the PSC inspection results, inspected ship selection scheme, effect of PSC inspection and suggestions to improve PSC inspection. We found that both ship factors and non-ship factors would influence the PSC inspection outcomes, and the PSC inspection could improve the safety level of maritime industry and protect marine environment. Meanwhile, there is still room to improve the PSC inspection, including adopting more efficient methods to select high risk ships, constructing combined databases and harmonization the PSC inspection authorities. It is expected that more research in improving and summarizing the PSC inspection will emerge in coming years. We believe that this review can shed light on the development of PSC related studies.

1. Introduction

Maritime transportation is playing an important role in the development of globalization [1]. Meanwhile, accidents and incidents aroused by maritime transportation render threats and risks to the marine environment [2]. To improve the situation, there are an increasing number of international conventions to maintain marine safety, crew training and pollution prevention. These regulations include but not limited to SOLAS, MARPOL, STCW, Tonnage Measurement, and Load Line conventions [3]. Generally, the flag state of the ships is responsible to ensure the ships flying its flag to meet the convention standards. However, many ships may irregularly visit their flag state ports and this would restrict the enforcement of flag state on its ships. Under such circumstance, the first Memorandum of Understanding (MoU) on Port State Control (PSC) was found in Europe in 1982, which is often referred to as "Paris MoU" [4]. The basic idea of

PSC is that the port states can have the right to inspect the coming foreign ships to ensure that they are safe and unlikely to pollute their water (Li and Zheng, 2008). With the support of the International Maritime Organization (IMO) and the International Labour Organization (ILO), the scale of Paris MoU is growing and the number of MoUs in the whole world is increasing. Nowadays, there are totally nine PSC MoUs all over the world aiming to eliminate substandard shipping.

Due to the limited resources and the high inspection cost, the PSC MoUs are unable to inspect all coming ships. As a result, one critical issue faced by the PSC MoUs is how to select ships to be inspected. Currently, one typical method adopted by PSC authorities is to set an inspection rate first in order to ensure the minimal number of inspected ships, then to use target factors attached with weighting points to identify high-risk ships. The target factors include ship characters (e.g., ship age, ship flag, ship recognized organization and ship type) and previous inspection records (e.g., last inspection time and precious detention time). In addition, the overriding factors, such as collision, grounding or stranding on the way to the port and an alleged pollution violation, etc., will also lead to an inspection [5].

When a ship is selected to be inspected, the port state control officer (PSCO) will first conduct an initial inspection, which mainly includes the first impression of the ship, certificate check and “walk around” to check the overall ship conditions. If major problems are found, clear grounds will be conducted before moving to an in-depth inspection, which is focused on the ship’s equipment, construction, manning, and working and living conditions. When the inspection is finished, an inspection report will be generated, in which the conditions that do not obey the conventions are denoted as “deficiencies” (including the deficiency number and deficiency types). If the PSCO decides that the ship is unsafe to the maritime environment, the ship can be detained until the deficiencies are rectified. The deficiencies and detention of the ship are called the PSC inspection results. The inspection results combined with the ship information will be recorded in the database of the corresponding MoUs.

2. Literature search method and review structure

Since the first PSC program was introduced by the IMO in 1982, the PSC inspection has been receiving increasing attention from researchers and policy makers. To access related papers, we searched the database of Google Scholar, Web of Science, and Scopus by using the keywords Port State Control or Port State Controls. A total of 43 papers that are principally focused on PSC inspection were found. In terms of their topics, we divide the literature into four areas: factors influencing the PSC inspection results, inspected ship selection scheme, effects of PSC inspection and ways to improve the PSC inspection. Specific, factors that influence the PSC inspection including ship factors and non-ship factors and the effects of PSC inspection contain the effects on maritime safety, effects on

inspected ships and effects on the environment protection. The overview of literature classification is illustrated in Figure 1.

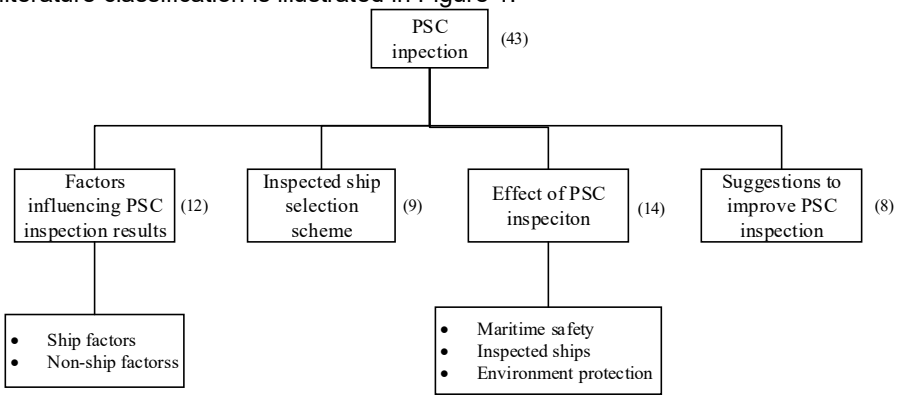

Figure 1. Structure of the review

3. Factors influencing the results of PSC inspection

Much of the current literature considers the factors that could affect the PSC inspection results. Some of those factors are ship factors, including the ship generic factors (e.g., ship age, ship type, ship size, the performance of ship flag and ship company, etc.) and ship inspection factors (e.g., the number of previous detentions, the number of outstanding deficiencies, etc.). A small number of studies focus on the non-ship factors, including the impact of PSC inspection time, inspection area and the background of the PSC inspectors. In some papers, the abovementioned factors have been analyzed simultaneously.

3.1. Ship factors influencing PSC inspection results

Some papers are focused on generic factors. Cariou et al. reported that ship age, type, and flag are the dominant predictors of ship deficiencies by using Poisson models constructed from 4,080 observations [6]. Cariou et al. then further identified that the determinants of PSC inspection results were ship age (40%), ship recognized organization (31%) and place of inspection (17%) based on 26,515 PSC inspections [7]. Recently, Yang et.al identified the factors that were most influential to bulk carriers' detention were the detected deficiency number, inspection type, ship recognized organization and ship age by using a data-driven Bayesian network [8].

More detailed ship factors are also identified in the literature. Cariou presented a quantile regression model and concluded that bulk vessels, dry cargos, and reefer

ships, as well as older ships were with a higher number of deficiencies and probability of detention [9]. Tsou used big data methods to analyze the inspection data and claimed that ships that are more than 25 years old, with less than 8,500 gross tonnages, of general cargo/multi-purpose type, at some certain year and place to be inspected and of some certain flags might perform worse in the PSC inspections [10].

3.2. Non-ship factors influencing PSC inspection results

Regarding mainly to non-ship factors, Knapp and Franses were the pioneers who used the econometric methods to analyze the influencing factors. In 2007, they proposed a logistic regression model based on 18,319 inspections globally to identify the differences in probability of detention and identified deficiencies. They claimed that the inspection areas and different background of inspectors would influence the inspection results [11]. Ravira and Piniella, and Graziano et al. both pointed out that the professional profile of PSC inspectors might have an impact on the inspection results [12, 13].

The abovementioned papers all use statistical models (regression model, count data model and variance decomposition analysis) to apply to case data sets and find out the determinant factors of PSC inspection results. The conclusions indicate that both the factors related directly to ships and to PSC inspections will both impact the inspection results.

4. Ship selection scheme in PSC inspection

How to select inspected ships in the PSC inspection is a critical issue. Not all foreign ships coming to the port states will be inspected due to the limited time, budget and human resources. However, if sub-standard ships are not identified and the deficiencies are not rectified, the safety and health of maritime environment will be damaged.

A considerable amount of literature has been focused on the ship selection scheme to make the selecting process more efficient. For example, in 1999, Li proposed a new ship assessment system to automatically give each coming ship a risk score based on its age, flag, insurers, classifications and operators [14]. Similarly, Degré demonstrated a high risk vessels selection scheme based on “Risk Concept” which combined ship generic variables with the Paris MoU criteria [15].

Several studies use the machine learning models for ship selection in PSC inspections. Xu et al. demonstrated a Support Vector Machine (SVM) risk assessment system based on target factors in order to classify the ships into high risk group or low risk group [16]. They then combined website scrapper technology

to extract more target factors and then included in the SVM model to improve its accuracy [17]. Based on these studies, Gao et al. further improved the classification accuracy of the proposed SVM model by combing K-Nearest Neighbor (KNN) method to remove noisy training examples [18]. In addition, Zhou and Sun introduced a new mathematical model which could be automatically optimized and self-evolved by using Generalized Additive Modeling (GAM) [19].

Overall, these studies all take factors related to ship itself, including the ship age, flag, type, company, and size into account when analyzing the results of PSC inspection. Conversely, the factors related to historical inspection information, such as the last inspection time, the previous number of detentions and the last inspection authority are seldom included in the above studies. In addition, the dynamic factors of the ships, such as the change of flag, change of ship company or classification society and change of captain and sailors are not considered in the above papers. Regarding the methodology proposed in these studies, they all use mathematical models to quantitatively illustrate the influence of the factors on PSC inspection results. Compared with the ship selection methods adopted by most of the PSC MoUs, these models can identify sub-standard ships more efficiently and accurately.

5. Effect of PSC inspection

While the flag state is seen as the first line of defense in eliminating substandard ships, the port state is seen as the second line [11]. After the first PSC program was introduced in 1982, a large volume of studies has discussed the effects of it. Basically, the effects of PSC inspection are in three aspects: effect on maritime safety, effect on inspected ships and effect on environment protection.

5.1. PSC inspection effect on maritime safety

The main research stream of this topic focuses on the effectiveness of PSC inspection on improving maritime safety. Knapp and Franses used combined data sources to identify how PSC inspections would affect the probability of casualty. They figured out that the casualty probability can be reduced after the PSC inspections conducted [11]. In addition, Li and Zheng concluded that the PSC programs were powerful in improving the maritime safety level by reducing total accident loss number and loss rate [20]. More specific, Knapp et al. provided a monetary quantification to estimate the incident cost savings brought by PSC inspection. They figured out that the estimated range of monetary benefit of PSC inspection was from about 70,000 to 190,000 dollars [21]. Regarding the specific relationship between ship inspection factors and accident involvement, in 2014, Hänninen and Kujala proposed a Bayesian network model and identified that the ship type, PSC inspection type and the number of deficiencies related to structural conditions were the most influential factors of accident involvement [22]. Hänninen

et al. then constructed another Bayesian network model and claimed that ship safety management could be highly improved after the PSC inspection [23]. Recently, Heij and Knapp investigated the predictive power of the PSC inspection by identifying that a worse PSC inspection outcome in the previous year, the higher probability of shipping accident in the next year [25]. The above papers all aim to validate the effectiveness of PSC inspection. Regarding the effectiveness of PSC inspection on the Maritime Labor Convention, Grbić et al. stated that it was becoming forceful in detecting unacceptable working and living conditions for crew onboard [24]. On the contrary, Bateman pointed out that the PSC inspection appeared to be inefficient in reducing the substandard ships in the Indian Ocean Region (IOR) where a large number of piracy, robbery, and other illegal activities still existed [26].

Overall, although PSC inspection may be inefficient in some developing world due to the complicated conditions and limited resources, the introduction of PSC can help improve the safety of the global maritime environment, especially by reducing the occurrence of maritime accident and the maritime risk loss rate.

5.2. PSC inspection effect on inspected ships

Another research stream is the effect of PSC inspections on the inspected ships. Cariou et al. suggested that the deficiencies detected in the next PSC inspection would be 63% fewer than that of the last inspection [27]. As the ship selection schemes adopted by PSC MoUs took ship flag and classification society into account, Cariou and Wolff proposed a bivariate Probit model and figured out that the PSC inspection might lead to ships' decisions on changing flag (flag-hopping) and classification society (class-hopping) [28]. Fan et al. also argued that PSC inspection might increase the possibility of flag-out [29].

5.3. PSC inspection effect on environment protection

Apart from the abovementioned two research streams, some researchers also observed the influence of PSC inspection on environment protection. Titz pointed out that PSC inspection was confirmed to be effective in reducing marine environment pollution [30].

Together, these studies outline that PSC inspection is impactful in reducing maritime risks, improving the condition of ships and protecting the maritime environment. However, there may be some drawbacks brought by the PSC inspections. As the ship selection scheme for PSC inspection takes the performance of ship flag and classification society into account, this may give rise to opportunistic behaviors including ships' flag-hopping and class-hopping to reduce their inspection frequency.

5.4. Suggestions for PSC inspection

A number of authors have given advice on PSC inspections in order to improve the inspection efficiency and accuracy. Bang and Jang identified the performance of nine MoUs were varied and thus advised establishing a system in which more advanced MoUs could assist those less advanced MoUs [31]. After interviewing experts, doing Analytic Hierarchy Process (AHP) analysis and evaluating questionnaires, Liou et al. suggested an optimal solution for restructuring Taiwan's PSC inspection authority was to establish an independent government agency under the Ministry of Transportation and Communications [32].

Harmonization of PSC MoUs' databases and combining with other inspection reports and casualty databases have been suggested in many papers, including but not limited to Knapp and Franses [33], Knapp and van de Veldon [34], Knapp and Franses [35] and Heij et al. [36].

Game models are also adopted in some papers. Li and Tapiero outlined a game model between the port authority and ship operators based on a random payoffs game-theoretical framework [37]. Yang et al. proposed a risk-based game model between ship owners and port authorities to figure out the optimal inspection policy. Based on the Nash equilibrium, port authorities optimal inspection rates and ship owners optimal maintenance rates were generated [8].

In view of all that has been mentioned so far, there is no doubt that PSC inspection is effective in rectifying substandard ships and improving maritime safety. Nevertheless, there is still room to develop its inspection strategies by adjustment of PSC inspection authority, combining databases of different MoUs, and with accident and casualty reports, or adopting some mathematical models to better tradeoff the inspection costs and rates.

6. Future research opportunities

As the economic development and world trade depend largely on maritime transportation, PSC inspection will become a more and more essential guard of maritime safety. Undoubtedly, more studies will further evaluate as well as improve the effectiveness of PSC inspection. We will outline some promising future research directions of PSC inspection.

To develop more efficient ship selection schemes, one possible way is to combine different databases, including among different PSC MoUs and with the ship information databases, maritime accident and incident databases and databases of other inspections in order to get more comprehensive case data sets. Also, more historical data can be taken into account when developing ship selection schemes despite the access difficulties, as the ship inspection history is a strong indicator for future inspection results. In addition, more advanced methods can be adopted,

especially those machine learning methods that are good at classification and prediction.

In recent years, marine environment protection and human factors of ship operations are receiving more attention than before [38-39]. As a result, PSC authorities are focusing more on onboard living and working conditions as well as maritime pollution caused by substandard ships [36]. However, there are few papers that are related to the effect of PSC inspections on protecting the marine environment and improving onboard conditions. Thus, future research should further evaluate the effects of PSC inspections on these two areas.

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