STATISTICAL ANALYSIS OF SHIP DEFICIENCIES WITHIN THE SCOPE OF PORT STATE INSPECTIONS (PSC): KOCAELI PORT APPLICATION

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Abstract

Maritime transportation is widely regarded as one of the cornerstones of global trade, and ship inspections play a critical role in maintaining safe transportation. Port State Control (PSC) is an inspection system that checks the safety and environmental standards of foreign-flagged ships to ensure compliance with international regulations.In PSC inspections, the age and type of ships are among the determining factors in the deficiency detection process. The present study undertakes an examination of the results of PSC inspections carried out in Kocaeli ports, with an analysis of the effect of ship type and age on deficiency rates. The study utilises the Analysis of Variance (ANOVA) method (one of the statistical analysis techniques) to compare deficiency rates according to different ship types and age groups, and to evaluate the frequency of inspection of ships according to risk level. The results reveal that ships aged 12 years and older have more deficiencies, with general cargo ships in particular requiring more stringent inspections. While the efficacy of inspections was found to be substantial, it was determined that the process should be made more efficient. In this context, it is recommended that ship risk assessment criteria should be expanded and inspection processes should be optimised according to ship age and type. In addition, it is hypothesised that better preparation of ship operators before the inspection may increase the effectiveness of the process. The aim of this study is to evaluate the effectiveness of PSC inspections in Kocaeli, one of the largest ports in Turkey, and to provide recommendations to improve the safety of maritime transportation.

Keywords: Port state control, Kocaeli port, ship safety, ANOVA, international regulations

1. INTRODUCTION

Maritime transportation is a key component of global trade, ensuring an essential role in sustaining economic activities worldwide. Millions of tons of cargo are transported via sea routes annually, requiring stringent regulations and oversight to ensure operational safety, efficiency, and environmental protection. Effective enforcement of these regulations depends on well-structured inspection mechanisms aligned with international maritime legislations. One such mechanism, Port State Control (PSC), is a vital tool for monitoring foreign-flagged vessels' compliance with international safety, environmental, and labor standards.

PSC inspections are conducted by port authorities to verify whether visiting their ports foreign flagged ships adhere to international maritime agreements and operational requirements. These assessments focus on safety management, pollution prevention measures, crew working conditions, and vessel operational integrity. The International Maritime Organization (IMO) has established these frameworks to enhance ship safety and minimize marine pollution risks. By identifying substandart vessels, PSC inspections help prevent maritime accidents and reduce environmental hazards .

Türkiye's strategic position in global trade makes it a significant maritime hub, with Kocaeli Port serving as a crucial gateway for international shipping. Situated in the Marmara Region, Kocaeli Port facilitates extensive cargo movement between Europe and Asia, attracting a high number of foreign-flagged vessels. This high traffic volume underscores the importance of rigorous PSC enforcement at the port. The findings from these inspections provide critical insights into both national maritime safety and the broader application of global maritime governance.

This study examines PSC inspections at Kocaeli Port, focusing on their efficiency, vessels' compliance levels, and their overall impact on maritime safety, environmental responsibility, and adherence to international regulations. Additionally, the research identifies areas for process optimization and offers recommendations for enhancing PSC procedures. The outcomes of this study hold significance not only for the Turkish maritime sector but also for global maritime stakeholders aiming to improve regulatory compliance.

PSC plays an indispensable role in ensuring safer and more sustainable maritime operations. The core objectives of these inspections include strengthening vessel safety, mitigating environmental risks, and safeguarding crew welfare. Additionallt, they provide valuable guidance for shipowners , port authorities maritime professionals in maintaining compliance with international standards. However, the true effectiveness of PSC depends not only on the existence of regulations but also on their consistent and accurate

enforcement. By analyzing the PSC inspection data at Kocaeli Port, this study contributes to identifying key areas for improvement in maritime safety and environmental conservation. The findings serve as an essential reference for both industry professionals and academic researchers seeking to enhance the effectiveness of port inspections worldwide.

2. LİTERATURE REVIEW

Numerous studies in the maritime field have focused on Port State Control (PSC) inspections. The significance of PSC arises from the fact that nearly half of flag States demonstrate substandard overall performance, making these inspections essential for ensuring compliance (Kara, 2022). PSC inspections serve as the final checkpoint to prevent the operation of substandard vessels, gaining increasing importance within International Maritime Organization (IMO) (Farag, 2016). However, although the primary objective of PSC is to identify non-compliant ships, a significant number of inspections do not result in detected deficiencies or detentions (Cariou & Wolff, 2015). This outcome is influenced by ship selection criteria. Supporting this, Wang et al. (2019) developed a classification model based on the Tree-Augmented Naïve Bayes (TAN) method, demonstrating that their model identified 130% more deficiencies than the conventional Ship Risk Profile selection approach. Additionally, Im and Sin (2017) investigated the root causes of deficiencies and concluded that many ships fail to adequately prepare for PSC inspections.

To enhance the effectiveness and efficiency of PSC inspections, various regulatory regimes are in place. In this regard, Xiao et al. (2021) analyzed global PSC regimes using the Super-Slack-Based Measurement (Super-SBM) and Malmquist Productivity Index (MPI) methods. Their findings indicated that the New Inspection Regime (NIR) is more cost-effective, efficient, and stable compared to other inspection frameworks.

Vessel characteristics, such as ship type and age, are key determinants of deficiency rates. Fu et al. (2020), utilizing correlation analysis, found that ship age and type significantly influence deficiency rates in PSC inspections conducted under the Tokyo MoU. Similarly, Gezici (2024) employed Bayesian networks and machine learning techniques to analyze PSC inspection results under the Mediterranean MoU in Türkiye, concluding that ship deficiencies are closely linked to vessel age and type.

Several studies have identified critical factors influencing PSC inspections. For instance, Yang et al. (2018) examined PSC inspections within the Paris MoU and determined that the most significant factors affecting inspections were the number of deficiencies, inspection type, Recognized Organizations (ROs), and ship age. Additionally, Öztürk et al. (2016) identified insufficient specialization among inspectors as the most influential factor impacting PSC inspections.

These studies emphasize the need to improve selection criteria, enhance regulatory frameworks, and increase the readiness of vessels to achieve more effective Port State Control (PSC) inspection results. However, there is no study specifically analyzing PSC results for Kocaeli, Türkiye's largest port and identifying the missing criteria in the current vessel selection process.

3. METHODOLOGY

In this study, a quantitative analysis method was employed. The primary objective of the research is to analyze the results of Port State Control (PSC) inspections conducted under the Mediterranean Memorandum of Understanding (MoU) at ports in Kocaeli, aiming to determine which ship types and age groups pose higher risks. To achieve this, inspection data was extracted from THETIS-Med, the official information system of the Mediterranean MoU, and analyzed using Analysis of Variance (ANOVA) within the Statistical Package for the Social Sciences (SPSS) software. The methodology is structured into key subsections detailing sample selection, data collection processes, and data analysis techniques.

3.1. Sample Selection and Criteria Development

The study includes data from 1,834 ship inspections conducted between 2020 and 2024 under the Mediterranean MoU across 37 port facilities within the administrative jurisdiction of Kocaeli. Given the structural similarities between Paris MoU and Med MoU information systems and the alignment of Med MoU inspection procedures with those of Paris MoU, the ship selection criteria established by the Paris MoU were adopted in this study.

Ships were categorized based on their type and age, resulting in two distinct risk groups:

- LRS (Low Risk Ship)
- HRS (High Risk Ship)

The ship types included in the analysis are:

- Oil tanker
- Chemical tanker
- Liquefied gas tanker
- Bulk carrier
- General cargo ship
- Container
- Ro-Ro

Ship age was classified into two groups:

- Ships aged 12 years or younger
- Ships older than 12 years

This classification enabled a more structured examination of the relationship between ship characteristics and the number of deficiencies recorded during PSC inspections.

3.2. Data Collection

The THETIS-Med information system, developed by the European Maritime Safety Agency (EMSA), was used to retrieve PSC inspection data from Mediterranean MoU member states. Within this framework, Kocaeli Port was selected, and inspection results from the period 2020-2024 were systematically reviewed. The extracted data served as the foundation for this research, providing a comprehensive overview of deficiencies detected in different ship types and age groups.

3.3. Data Analysis

Before analyzing the collected data, research hypotheses were formulated as follows:

- Null Hypothesis (H_0): Ship age ship type do not have a statistically significant effect on the number of deficiencies detected in PSC inspections.
- Alternative Hypothesis (H_1): Ship age and ship type have a statistically significant effect on the number of deficiencies detected in PSC inspections.

The dataset was then analyzed using ANOVA, a widely recognized statistical method for comparing group variances, to examine the correlation between ship deficiencies and ship characteristics. The analysis was conducted within the SPSS software environment, ensuring a robust quantitative approach to validating the study's findings.

4. FINDINGS

A subset of the 1,834 inspected ships, categorized based on ship age and risk classification (Low-Risk Ships - LRS and High-Risk Ships - HRS), is presented as a sample dataset in Table 1. The findings provide valuable insights into the relationship between ship characteristics and deficiency levels, reinforcing the necessity of refining risk assessment methodologies to enhance the effectiveness of port state inspections.

Table 1. Number of deficiencies based on risk based ship type and age

Ship	***Ship Type***	***Ship Age***	**The Risk for Ship Age**	**The Risk for Ship Type**	***The Number Of Deficiency***
Ship 1	*General Cargo*	*15*	*HRS*	*LRS*	*5*
Ship 2	*Chemical Tanker*	*22*	*HRS*	*HRS*	*1*
Ship 3	Liquefied *Gas Carrier*	*22*	*HRS*	*HRS*	*1*
Ship 4	*Bulk Carrier*	*18*	*HRS*	*HRS*	*0*
Ship 5	*Oil Tanker*	*16*	*HRS*	*HRS*	*1*
Ship 6	*Container*	*12*	*LRS*	*LRS*	*2*
Ship 7	*Ro-Ro*	*12*	*LRS*	*LRS*	*1*

As a result of the analysis conducted with the ANOVA method using SPSS, information on ship type, ship age and their effects on the number of deficiencies is given in Table 2.

Table 2. Interaction results of ship type and age with the number of defects

Source	Type II Sum of Squares	Degrees of Freedom	Mean Square	F Value	Significance
Corrected Model	499,779	3	166,593	54,098	0,000
Intercept	3983,756	3983,756	1	3983,756	0,000
Ship Type	88,741	1	88,741	28,817	0,000
Ship Age	265,456	1	265,456	86,201	0,000
Ship Age*Ship Type	27,381	1	27,381	8,891	0,003
Error	5635,465	1830	3,079		
Total	10119,000	1834			
Corrected Total	6135,244	1833			

5. DISCUSSION

According to the findings of this study, ships aged 12 years or younger exhibit significantly fewer deficiencies, whereas vessels older than 12 years tend to have a considerably higher number of deficiencies. Ship age has been identified as the most influential factor affecting the number of deficiencies detected. The statistical analysis confirms that older ships display a significantly higher number of deficiencies compared to younger vessels. In other words, as a ship's age increases, the number of deficiencies also rises. Similarly, Fu et al. (2020) concluded that ship age plays a crucial role in determining deficiency levels, identifying it as one of the most critical factors influencing inspection outcomes. These findings suggest that older ships are either subject to more maintenance and operational deficiencies or that they are utilized more intensively, leading to a greater number of issues over time. On the other hand, younger ships are observed to comply more effectively with international safety and operational standards.

In addition to ship age, ship type also has a statistically significant impact on the number of deficiencies.

While it would be expected that high-risk ship types would exhibit a greater number of deficiencies, the findings reveal a counterintuitive trend low-risk ship types, rather than high-risk ones, show a more substantial influence on the total number of deficiencies detected. Among different ship types, general cargo ships are identified as the vessels with the highest number of deficiencies, making them the most influential in terms of deficiency impact. The role of ship type, particularly general cargo ships, in determining deficiency levels is supported by the findings of Gezici (2024). However, previous studies, including those by Gezici and others, have not specifically emphasized the observation that low-risk ships have a greater impact on deficiencies than high-risk ships.

When considering ship age and ship type together, the results indicate that these two factors collectively have a significant effect on the number of deficiencies detected in ships. The most deficiency-prone category consists of older ships classified under low-risk ship types. Following this category, ships that are both old and of high-risk types also exhibit a substantial number of deficiencies. Conversely, the lowest deficiency levels are observed in vessels that are both young and categorized under low-risk ship types. These findings highlight a critical implication for port state control authorities: from the perspectives of navigational safety, human life, cargo security, and environmental protection, the highest-risk vessels are those that are relatively old yet classified as low-risk ship types—such as general cargo ships. Supporting this conclusion, the study by Cariou and Wolff (2015) also found that the highest numbers of deficiencies and detention rates were observed in livestock carriers, general cargo ships, refrigerated vessels, and RORO ships older than 30 years.

These findings underscore the necessity of a more nuanced approach in ship inspections, particularly for older vessels categorized under lower-risk ship types. Regulatory authorities may need to reassess traditional risk classification methods to ensure that such ships receive adequate scrutiny, as their operational and maintenance deficiencies could pose significant risks despite their lower-risk classification.

6. CONCLUSION

Under the framework of the Mediterranean MoU, Turkey has been identified as the country conducting the highest number of inspections, with the largest port city, Kocaeli, playing a central role in this process. The significant number of inspections carried out in Kocaeli reflects the importance placed on maritime safety within this port. As a result of these extensive inspections, a substantial dataset has been generated, providing reliable and consistent findings for this study.

The analysis confirms that older ships exhibit the highest number of deficiencies, making them a considerable risk factor for port state control authorities in terms of navigation safety, human life, property protection, and environmental sustainability. To mitigate these risks, it is essential to implement more rigorous maintenance, repair, and operational practices for aging vessels, ensuring that their long-term functionality aligns with international safety standards. Enhancing the sustainability of these maintenance efforts is expected to play a key role in reducing the number of deficiencies observed in such vessels.

Another significant finding of this study is that, contrary to common expectations, ships categorized as low-risk in terms of type were found to have a higher number of deficiencies compared to high-risk ship types. Among all ship types, general cargo ships recorded the highest number of deficiencies, suggesting that current risk profiling and ship selection criteria for inspections may require revision. By refining these classification methods, the efficiency and effectiveness of ship inspections can be improved ensuring that potential safety hazards are identified more accurately.

When ship type and ship age are analyzed together, the most critical category in terms of deficiencies consists of older ships classified under low-risk ship types. This finding suggests that, to further strengthen maritime safety, older general cargo ships should be prioritized in inspections. In addition, older container ships and Ro-Ro vessels should also be subjected to more frequent and thorough inspections compared to other ship types. Additionally, targeted concentrated inspection campaigns should be implemented, particularly for general cargo ships, to ensure stricter compliance with safety and maintenance standards.

This study is derived from the master thesis titled “Analysis Of Port State Control (PSC) Inspection Results For Ships: The Case Of Kocaeli Port”.

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