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The Effect of Inspection on Competition in Maritime Transportation: An Analysis of Oil Tankers

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Abstract

In maritime transport, the cornerstone of global trade, the inspection processes of ships stand out as a critical factor that directly affects competition. International ship inspection regimes shape the dynamics of sectoral competition by assessing the extent to which ships comply with international legislation. In this study, Paris MoU's inspection data for six years (2019-2024) divided into 24 quarters are analyzed and competition analysis is conducted according to the age of oil tankers using the Ship Inspection Competition Index (SICI). In addition, forecasts for all quarters through the end of 2025 were generated using ARIMA model based on SICI results. The results show that removing oil tankers from the fleet when they reach 10 years of age would be an appropriate strategy for shipping companies to maintain and improve their competitive advantage. It is evaluated that this study can provide significant benefits in fleet management and strategic decision-making processes in the maritime industry, and also provides a valuable academic framework for measuring current competitive dynamics and predicting future trends with the integration of SICI and ARIMA methods.

Keywords: Competition, Inspection, Maritime business management, SICI, ARIMA

1. Introduction

Maritime transport is one of the most important components of global trade and plays a vital role in the sustainable functioning of the world economy. Inspection mechanism is an effective tool to prevent possible damages that ships, the main element of the sector, may cause to people and the environment for various reasons. Inspection and competition are two fundamental elements that interact with each other in maritime transport sector. The Paris Memorandum of Understanding (MoU) directly affects the technical competence and competition conditions of ships in maritime trade by evaluating the technical competence of ships. In other words, PSC inspections directly affect ships with sanctions that may lead to detention and cause ships to be disadvantaged in terms of competition.

Competition in the maritime sector is not only a price-oriented phenomenon; it is considered as a multidimensional process involving various factors such as safety and compliance with legislation. In this process, inspections stand out as one of the main determinants of competition, and the way commercial ships are subjected to inspection processes directly affects competitiveness. Increasing competition conditions force businesses to fulfill their responsibilities [1]. One of the most important aspects of the concept of competition is that it provides a broader comparison opportunity [2]. Current situation comparisons and competition measurements made in terms of the development of countries and the sustainability of companies allow for the testing of future targets and a more accurate analysis of sectoral dynamics [3-6]. In this context, the evaluation of competition in the maritime sector should be addressed not only through economic indicators, but also through the inspection results of ships.

Inspection mechanisms and the indicators resulting from these inspections are among the most important factors

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determining the competitiveness of ships. This study analyzes the effects of inspection processes on competition. It is evaluated that this approach will play an important role in strategic decision-making processes for stakeholders operating in the maritime transport sector.

2. Literature Review

In the literature, the concept of competition is handled comprehensively within the framework of different disciplines such as economics, business, sociology and politics, and various theoretical and empirical studies have been carried out in these areas. These studies, which examine the different dimensions of competition, have made significant contributions to the literature with different approaches and practical analyzes. The examination of the studies that are carried out in the literature and form the basis of competition in the literature is considered important in terms of contributing to a better understanding of the concept of competition in maritime literature and creating a solid theoretical framework. In this respect, the literature screening of the study was carried out systematically under the following five main headings.

- Academic studies on the foundations of competition
- Competition indexes in global literature
- Competition and inspection-related studies in maritime literature
- Indexes used in maritime literature
- The ARIMA method and forecasting model in literature

2.1. Academic Studies on the Foundations of Competition

Approaches to competitiveness are divided into two main categories: classical and modern. The foundations of the classical approach were first discussed in Adam Smith's "Wealth of Nations" in 1776. In this context, the first theoretical infrastructure of the classical approach was built on the theory of absolute superiority. This theory, developed by Adam Smith advocates free trade and specialization that will emerge as a result of this trade. Specialization increases productivity in production processes based on the principle of labor department, promotes more effective use of world resources and ultimately contributes to the increase in global prosperity. According to Smith, competition is defined as the ability to harmonize and respond to the changes in market conditions. Companies can maintain their competitiveness to the extent that they can effectively adapt to changes in the markets. In this context, competition is considered not only as an economic phenomenon but also as a fundamental mechanism that shapes market dynamics [7]. The Theory of Absolute Advantage, put forward by Adam Smith, has an important place in explaining the basic dynamics of international trade. However, this theory was insufficient to cover all the elements that determine the trade between countries. In particular, it cannot provide explanations about how trade will take place in cases where any country does not have absolute superiority. To eliminate these deficiencies, David Ricardo has made the concept of absolute superiority more comprehensive and applicable with the Theory of Comparative Advantage. Ricardo has revealed this theory in his work in 1817, "Principles of Political Economy and Taxation". According to the theory of comparative advantage, even a disadvantaged country can trade by specializing in the production of goods in which it is relatively less disadvantaged. From this perspective, when each country realizes and exports the goods it produces, it will have a relative cost advantage, resources will be used more efficiently, and all parties involved in trade will benefit. Ricardo's approach is considered one of the most important elements of classical economic theory in terms of encouraging free trade and rationalization of the international division of labor [8]. Classical approaches explain international trade within the framework of the absolute and comparative advantages of countries. These approaches argue that countries of countries specialize in line with the factors of production, such as natural resources, labor force, and capital, will increase productivity. In contrast, modern approaches not only focus on traditional factors, but also analyze elements such as technology, innovation and knowledge and offer a wider perspective. Modern theories evaluate production processes in a more dynamic framework, taking into account factors such as R&D investments, human capital and infrastructure development, among the main elements that determine the competitiveness of the countries.

As a result of many years of research, Michael Porter published his work "The Competitive Advantage of Nations" and has associated competition with productivity, unlike the theory of comparative advantages. Porter emphasized that international competitiveness is not only based on natural resources or low cost advantage, but that productivity and innovation are critical for the competitive advantage. In this context, Porter has developed a framework called the "Diamond Model" to explain the competitive advantages of countries. This model includes four basic factors that determine the competitive advantage: firm strategy and competition structure, demand conditions, relevant and supportive industries, production factors. Additionally, Porter argues that competition takes place not only between nations but also at the firm level. Porter's approach has gained an important place in modern competition theories and has been widely adopted in the international business world [9]. Unlike traditional international trade theories, Paul Krugman [9] has discussed its competitiveness on a country basis, not on a firm basis. Krugman's [9] "New Trade

Theory" argues that international trade is shaped not only by comparative advantages, but also by differences in increasing returns and market structures, taking into account elements such as scale economies and entry barriers to the market. According to Krugman [9], the main factor that determines the competitiveness of countries is the competition strategies of the companies operating in the domestic market in innovation, productivity and global markets. In this context, competitiveness at the firm level directly affects the general economic performance of the country. Krugman's [9] model has been one of the important theories that shape today's international competition by offering a new perspective in terms of globalization, industrialization and trade policies [3].

Richard Whitley's Firms, Institutions and Management Control: The Comparative Analysis of Coordination and Control Systems (1999) provides a substantial theoretical contribution to the understanding of competition by emphasizing that it should not be interpreted solely as a process based on products, pricing, or efficiency [10].

Schumpeter [11] has dealt with competition as a dynamic process, not static, in his work, published in 1942, "Capitalism, Socialism and Democracy". Unlike traditional price-based competition, Schumpeter [11] argued that competition is shaped not only by cost advantages, but by the process of innovation and creative destruction [10]. According to Schumpeter [11], competition is a transformation mechanism in which companies try to leave their competitors behind by developing innovative products, production techniques and business models. While the companies that are successful in this process gain strength in the market, companies that cannot keep up with change are eliminated by losing their competitive advantages. Thus, economic growth and industrial development progress in a continuous renewal cycle. This approach of Schumpeter has made a significant contribution to modern competition theories, emphasizing the role of technological change and entrepreneurship in economic development.

In her Modern Competitive Analysis, Oster [12] argues that companies can achieve and maintain competitive advantage through effective strategic positioning and adoption of basic strategic approaches. According to Oster [12], the permanence of the competitive advantage is possible not only by firms strengthening their position in the current market, but also by taking into account elements such as strategic harmony, flexibility and innovation. In this context, companies should analyze industrial dynamics to maintain competitive advantages, adapt to changing market conditions and develop unique value suggestions compared to their competitors. Oster's [12] work contributes to the shaping of long-term success strategies of businesses by providing an important theoretical framework for strategic management and competition analysis.

Barney's [13] study, "Firm Resources and Sustained Competitive Advantage", underscores that competition takes place not solely among macro-level actors such as countries, but also at the micro level, among individual firms.

Deming [14] emphasizes that in Out of the Crisis, the basic criterion of competition is not price but quality, and that this quality is sustainable, depending on continuous improvement processes. According to Deming [14], it is not enough for firms to focus on the cost advantage for companies to achieve long-term success; Quality management, process improvement and customer satisfaction are also of critical importance. In this respect, the concepts of Total Quality Management (TQM) and stable process development stand out as basic strategies in preserving competitive advantage. Deming [14], in particular, argues that approaches such as data-oriented decision-making, employee participation and the continuous improvement cycle (*Plan-Do-Check-Act*-PDCA) are decisive in increasing the competitiveness of companies. Deming's [14] work has an important place in the development of modern quality management understanding and sustainable competition strategies.

2.2. Competitive Indexes in Global Literature

There are different indices used in the literature to calculate competitiveness. These indices have been developed to measure and compare the competition levels of countries or companies in the international market. In this context, one of the most commonly used indices is the Revealed Comparative Advantage (RCA) (Equation 1) and was developed by Balassa [15] in 1965. The RCA index aims to measure the relative competitive advantage of a country by comparing a country's export performance in a particular good or service with general trends in world trade. This method provides an objective analysis based on trade data and enables countries to evaluate the levels of specialization of countries on a sectoral basis [15].

$$RCA_{ij} = \frac{\left(\frac{X_{ij}}{X_j}\right)}{\left(\frac{X_{iw}}{X_w}\right)} \quad (1)$$

X_{ij} = country j's exports of goods i

X_j= country j's total exports

X_{iw}= world exports of goods i

X_w= total world exports.

If the described comparative advantages Index (RCA) value is greater than 1 (RCA> 1), it indicates that the country concerned has a comparative advantage in the production and export of a particular good. RCA = 1 implies that the export share of the country in this property is compatible with the global average and that it contains neither advantage nor disadvantage. In the case of RCA <1, it is considered that the country does not have a comparative advantage in the relevant goods, because its share in global trade is relatively lower.

The Relative Import Advantage - RMA index developed by Vollrath (1991) was created to relieve some deficiencies in the described comparative advantages (RCA) index of Balassa [15] (Eq.2). Although the RMA index has a similar structure to RCA, the main difference is that it uses and interprets import data instead of export. This index allows a country to analyze competition disadvantages by comparing the import share of imports in a particular product with the distribution in global trade [16].

$$RMA_{ij} = \frac{\left(\frac{M_{ij}}{M_{nj}}\right)}{\left(\frac{M_{ir}}{M_{nr}}\right)} \quad (2)$$

M_{ij}: country j's import of goods i,

M_{nj}: country j's import of all remaining goods,

M_{ir}: group of countries or whole world's import of goods i,

M_{nr}: group of countries or whole world's import of all remaining goods.

If the RMA index is greater than 1 (RMA>1), it indicates that the concerned country has a comparative disadvantage in a particular property. RMA = 1 implies that the country's share of imports in this goods is compatible with the global average and contains neither advantage nor disadvantage. In the case of RMA <1, it is considered that the country has a comparative advantage in the relevant goods.

Yalnız [17] has developed a technological index (*Revealed Technological Index*-RTI) to analyze the effect of technology on employment. This index aims to classify them according to their technological competencies by measuring the technological competitive advantages of the countries. In the study, the competitive advantages of the countries in technology-intensive sectors were evaluated by using RTI and the effects of technological development on employment were examined [17].

2.3. Competition and Inspection Related Studies in Maritime Literature

Knapp and Franses comparatively examined the port state control regimes implemented worldwide and analyzed the structural differences of these regimes in an econometric framework. In the study, the effectiveness of PSC regimes was evaluated by examining variables such as detention rates, inspection intensity, ship age, and flag state within the scope of different regional inspection regimes, especially the Paris MoU. Empirical findings show that regional differences in PSC practices are decisive on ship safety and inspection performance [18].

Akyüz et al. [19] used failure mode and effect analysis (FMEA) and rule-based fuzzy logic methods to analyze 310 deficiencies detected in 33 ships as a result of the "Fire Safety System" inspections carried out in line with the intensified inspection campaign carried out within the scope of the Black Sea MoU inspection regime in 2013. In the study, a systematic model was developed to increase on-board safety in line with the findings obtained and contributed to the increase in the effectiveness of inspection processes.

Dayan [20] examined the relationship between leadership style and innovation and the mediating role of competitive advantage in this relationship in the maritime sector example. The study reveals the strong relationship between leadership and innovation, while emphasizing the critical role of competitive advantage in this relationship. The results show that effective leadership and innovation are important for businesses to achieve a competitive advantage [20].

Arıcan et al. [21] analyzed the competition dynamics in the coaster market in Türkiye and evaluated the criteria determined based on expert opinions with the ELECTRE method. The findings show that ships in the 3001-5000 gross tonnage range have more advantages in terms of competition compared to other tonnage groups [21].

Durmuş [22], in his study on marine power management, focused on issues such as energy efficiency, renewable energy use and sustainability. The study emphasizes that energy management and optimization contribute to the competitive advantage in the maritime sector and the importance of marine power management [22].

Yorulmaz and Derici [23] analyzed the current status of digitalization in the maritime sector using scientific mapping. The study emphasized the effects of digitalization on efficiency and competitive advantage [23].

Hocek et al. [24] developed a binary logistic regression-based machine learning model to predict ship detention probabilities based on 16,533 inspection reports conducted in the Paris MoU region in 2023. The study presents an innovative decision support tool that contributes to risk-based inspection strategies by providing a data-driven view of PSC processes [24].

In their analysis of Turkish-flagged vessels inspected under the Paris MoU between 2011 and 2016, Yılmaz and Ece identified a higher detention rate among ships aged 13 years and above. This finding indicates a statistically significant relationship between vessel age and inspection outcomes. Similarly, the present study demonstrates a decline in the competitive strength of oil tankers aged 10 years and older, thereby supporting the existing literature on the influence of vessel age in maritime regulatory and competitive contexts [25].

2.4. Indexes Used in Maritime Literature

In maritime literature, various indexes are used to evaluate the energy efficiency, operational efficiency and logistics performance of ships. These indices have been developed to analyze elements such as sustainability, cost optimization and environmental impact management and are considered an important scientific basis in the field of maritime transportation.

The Logistics Performance Index (LPI) is an index developed by the World Bank and aims to measure the logistics efficiency of countries. The LPI consists of subcomponents such as the efficiency of customs procedures, infrastructure quality, regularity of international shipments, adequacy of logistics services, tracking and monitoring capabilities, and on-time delivery. This index allows countries to comparatively analyze their logistics performance and is considered an important criterion for evaluating the efficiency of trade and transportation processes. The LPI is calculated on a scale of 1 to 5, with a higher score indicating stronger logistics performance [26].

Another index widely used in maritime literature is the Energy Efficiency Existing Ship Index (EEXI). Developed by the International Maritime Organization (IMO), this regulation is implemented to measure the energy efficiency of existing ships and reduce global greenhouse gas (GHG) emissions. As a criterion for evaluating the technical energy efficiency of ships, EEXI plays an important role in achieving environmental sustainability goals in maritime transportation [27].

The Energy Efficiency Design Index (EEDI) was developed by the International Maritime Organization (IMO) and is a regulation put into effect to increase the energy efficiency of newly built ships and reduce greenhouse gas (GHG) emissions. By measuring the technical energy efficiency of ships, EEDI aims to encourage more environmentally friendly designs and strengthen sustainability standards in maritime transportation [28].

The Energy Efficiency Operational Indicator (EEOI) is an indicator developed by the International Maritime Organization (IMO) to measure the operational energy efficiency of ships. This indicator helps track CO_2 emissions by evaluating the actual operational performance of ships [29]. Yalnız and Çetin [30] analyzed the level of competition among different ship types based on inspection results within the scope of the Paris MoU and Med MoU, using the Ship Inspection Competition Index, which they developed. By going beyond traditional indices, the authors presented a quantitative, inspection-based assessment and revealed that general cargo vessels are at a disadvantage compared to other ship types in terms of competition. In this regard, the study offers a unique and significant contribution to the maritime literature by providing an index-based analytical framework supported by quantitative data to evaluate the impact of inspection processes on competition levels [30].

2.5. The ARIMA Method and Forecasting Model in Literature

Time series analysis is extensively utilized across disciplines such as engineering, natural sciences, social sciences and economics to investigate the temporal dynamics of variables and to produce forecasts regarding future behaviors. Within this framework, the ARIMA model is distinguished in the literature as one of the most widely adopted forecasting techniques, owing to its statistical robustness and structural flexibility.

Gilbert [31] employed the ARIMA model to predict inventory fluctuations and demand trends within supply chain systems, illustrating that ARIMA-based forecasting contributes significantly to more effective inventory management and enhanced operational performance. The study further underscores the model's versatility, demonstrating its application beyond traditional economic data to logistics and supply chain operations [31].

Kumar and Jain [32] employed the ARIMA model to predict the concentrations of key air pollutants, including ozone (O_2), nitric oxide (NO), nitrogen dioxide (NO_2), and carbon monoxide (CO). Utilizing air quality monitoring data from Delhi, India, they developed distinct ARIMA models for each pollutant. The findings revealed that the ARIMA approach achieved a high level of accuracy in short-term forecasting of ambient air pollutant concentrations [32].

Ariyo et al. [33] applied the ARIMA model to stock price forecasting, demonstrating its statistical reliability and effectiveness as a predictive tool across financial data.

Ospina et al. [34] conducted a comprehensive analysis of the ARIMA model's role in forecasting during the COVID-19 pandemic, using case data from Brazil. Applying the ARIMA(2,2,1) specification, the study demonstrated the model's high predictive accuracy, supported by visual analyses. The findings highlight ARIMA's practical reliability for decision-makers and reinforce its significance as a robust forecasting tool within the existing literature [34].

Lee et al. [35] employed ARIMA and SARIMA models in their study to forecast port container volumes. Using monthly data from the Port of Busan, their analysis demonstrated that the ARIMA model effectively captured and predicted short-term fluctuations in operational demand [35].

In summary, the literature identifies ARIMA as a statistically robust and versatile forecasting method, successfully applied across fields such as finance, supply chain management, environmental sciences, and public health. As a cornerstone of time series forecasting, ARIMA maintains its relevance in both research and practice, especially through its integration into hybrid models.

3. Methodology

In the maritime transport sector, especially in the oil tanker class, competition analysis is of great importance in terms of strategic decision-making processes and market forecasts. In this study, the competitive structure of oil tankers divided into four different age groups was examined using the Ship Inspection Competition Index, which measures the competitive status of ships through inspections. In addition, quarterly estimates were made for 2025 using the Autoregressive Integrated Moving Average (ARIMA) model and the future competitive dynamics of the sector were tried to be predicted. In the first stage of the study, competition analysis was carried out using the Ship Inspection Competition Index based on the deficiencies detected in the inspection results. In this stage, the competition structure in the sector was evaluated in line with the inspection performances of oil tankers. In the second stage, the future competition levels of oil tankers were estimated using the ARIMA method using the 24-quarter SICI values calculated between 2019-2024 for oil tankers separated by age groups. In the study, SICI and ARIMA time series methods were applied in an integrated manner, and forward-looking predictions were presented for the competitive dynamics of the oil tanker sector. In this study, the SICI, used to analyze the impact of inspection processes on competition, is based on the comparison between the ratio of deficiencies or detentions to the total number of inspections for a specific ship type and the corresponding ratio for all ship types (Equation 3). This metric serves as a critical indicator for assessing the competitive advantage or disadvantage of different vessel categories.

$$SICI = \frac{\left(\frac{M_{ij}}{M_{nj}}\right)}{\left(\frac{M_{ir}}{M_{nr}}\right)} \qquad (3)$$

Where;

$\sum I_{xr}$: The number of deficiencies or detentions detected during inspections for a particular ship type,

$\sum I_{xi}$: Total number of inspections carried out for a particular ship type,

$\sum I_{ar}$: Number of deficiencies or detentions detected during inspections for all ship types, $\sum I_{ai}$: Total number of inspections performed for all ship types.

The Ship Inspection Competition Index value is used as an important indicator to measure the competitive level of ships. If the SICI value is zero (SICI=0), it indicates that the ship is fully competitive. Ships with a SICI value between 0 and 1 (0<SICI<1) are considered to have a competitive advantage in the sector, while ships with a SICI=1 are considered to be at an equal competitive level with the sector average. If the SICI value is greater than 1 (SICI>1), it indicates that the ship has a competitive disadvantage. In this context, the SICI index is used as a critical criterion to analyze the competitive dynamics in the maritime transport sector and to determine the positions of ships in market conditions [30]. The definition of SICI ranges is presented in Table 1.

ARIMA is a statistical modelling method widely used in time series analysis and was developed by Box and Jenkins [36]. The main purpose of time series analysis is to model and understand the estimated mechanism by analyzing the structure and change dynamics of the observed series. It is also used to predict future values and make strategic decisions based on past data of the series [37]. The basic feature of time series is that the data is ordered in time and that consecutive observations are generally dependent on each other. This dependency allows for the analysis of relationships between periods and enables the creation of reliable predictions. Time series models are used as an important tool in predicting future trends by evaluating this dependency with statistical methods [38].

4. Results and Discussion

The basic data of this research is based on the results of 7.557 inspections conducted by Paris MoU PSC on oil tanker ships between 2019-2024. The number of inspections (NoI) conducted by Paris MoU PSC on oil tankers belonging to the age groups 0-5, 5-10, 10-15 and 15-20 in each quarter during the relevant period and the number of deficiencies detected in these inspections (NoD) are presented in detail in Table 2. This study was conducted on 10.270 deficiencies identified as a result of 7.557 inspections.

SICI deficiency values are calculated using the number of deficiencies (NoD) and number of inspections (NoI) data obtained through the Thetis system and are presented in detail in Table 3. THETIS Portal is a digital platform developed by the European Maritime Safety Agency (EMSA) to facilitate the management and coordination of inspections carried out by port state control mechanisms [39].

Based on the inspections carried out by the Paris MoU PSC between 2019-2024, the annual trends in SICI deficiency values of oil tankers according to their age groups are

Table 1. *Definition of SICI ranges*

SICI range	Definition
SICI=0	Perfectly competitive
0<SICI<1	Competitive advance
SICI=1	Equal competitive
SICI>1	Competitive disadvantage

presented in detail in Figure 1. In this context, the SICI deficiency values of oil tankers belonging to different age groups were analyzed in line with the changes they showed in the relevant years.

Table 2. *NoI and NoD values of inspections conducted by Paris MoU between 2019-2024*

Year	2019								2020							
Quarter	Q1		Q2		Q3		Q4		Q1		Q2		Q3		Q4	
Age of Vessel	NoI	NoD	NoI	NoD	NoI	NoD	NoI	NoD	NoI	NoD	NoI	NoD	NoI	NoD	NoI	NoD
0-5	51	16	75	40	72	19	73	30	71	35	37	8	66	33	75	13
5-10	82	68	102	74	82	64	74	70	67	49	38	17	59	35	55	55
10-15	115	142	126	173	142	257	151	250	131	186	64	125	133	86	97	127
15-20	33	49	68	129	61	72	81	142	67	114	35	60	97	100	56	85
Total	281	275	371	416	357	412	379	492	336	384	174	210	355	254	283	280
Year	2021								2022							
Quarter	Q1		Q2		Q3		Q4		Q1		Q2		Q3		Q4	
Age of Vessel	NoI	NoD	NoI	NoD	NoI	NoD	NoI	NoD	NoI	NoD	NoI	NoD	NoI	NoD	NoI	NoD
0-5	55	11	77	32	75	27	65	36	31	14	49	30	41	11	58	24
5-10	76	25	115	74	100	45	96	47	91	29	100	70	106	61	97	71
10-15	64	123	96	167	105	167	115	101	104	158	141	233	105	182	106	281
15-20	51	160	66	142	92	89	75	119	86	128	98	187	91	229	98	208
Total	246	319	354	415	372	328	351	303	312	329	388	520	343	483	359	584
Year	2023								2024							
Quarter	Q1		Q2		Q3		Q4		Q1		Q2		Q3		Q4	
Age of Vessel	NoI	NoD	NoI	NoD	NoI	NoD	NoI	NoD	NoI	NoD	NoI	NoD	NoI	NoD	NoI	NoD
0-5	47	23	43	18	53	22	51	20	44	28	38	36	35	28	29	25
5-10	95	48	67	41	77	65	68	74	84	93	69	62	83	104	53	54
10-15	110	301	105	199	86	134	75	138	75	130	76	186	67	131	80	181
15-20	98	272	83	215	82	316	78	303	89	232	82	199	89	341	85	247
Total	350	644	298	473	298	537	272	535	292	483	265	483	274	604	247	507

Table 3. *SICI-Deficiency values (2019-2024)*

Year	2019				2020				2021			
Quarter	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Age : 0-5	0.32	0.48	0.23	0.32	0.43	0.18	0.70	0.18	0.15	0.35	0.41	0.64
Age : 5-10	0.85	0.65	0.68	0.73	0.64	0.37	0.83	1.01	0.25	0.55	0.51	0.57
Age : 10-15	1.26	1.22	1.57	1.28	1.24	1.62	0.90	1.32	1.48	1.48	1.80	1.02
Age : 15-20	1.52	1.69	1.02	1.35	1.49	1.42	1.44	1.53	2.42	1.84	1.10	1.84
Year	2022				2023				2024			
Age of Vessel	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Age : 0-5	0.43	0.46	0.19	0.25	0.27	0.26	0.23	0.20	0.38	0.52	0.36	0.42
Age : 5-10	0.30	0.52	0.41	0.45	0.27	0.39	0.47	0.55	0.67	0.49	0.57	0.50
Age : 10-15	1.44	1.23	1.23	1.63	1.49	1.19	0.86	0.94	1.05	1.34	0.89	1.10
Age : 15-20	1.41	1.42	1.79	1.30	1.51	1.63	2.14	1.97	1.58	1.33	1.74	1.42

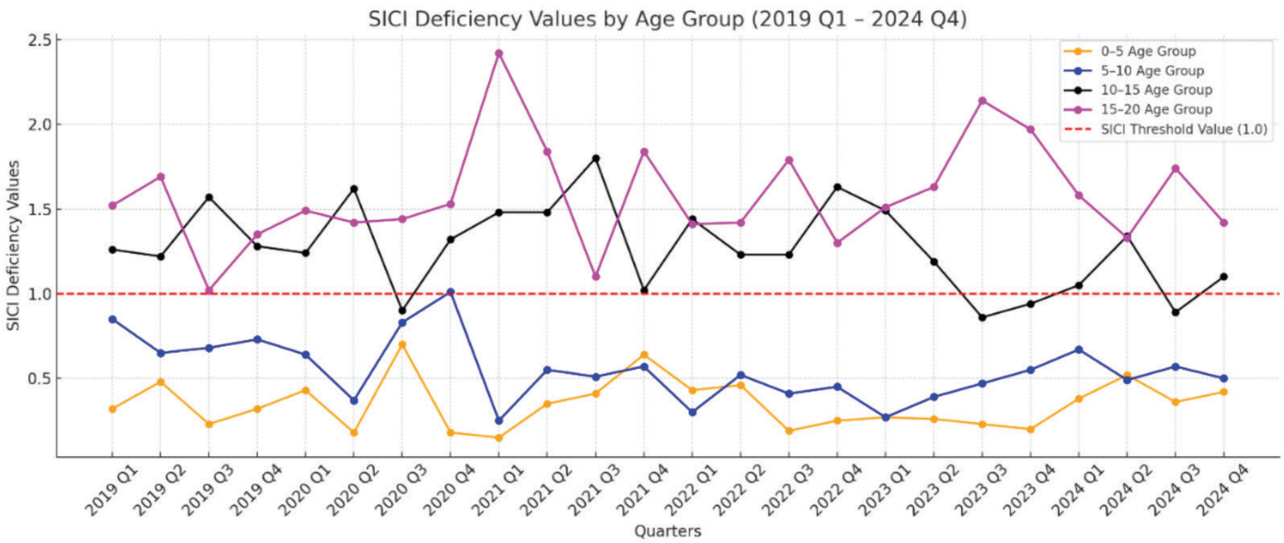

Figure 1. *SICI deficiency values by age group (2019-2024)*

In the second stage of the study, firstly, the most suitable ARIMA models were determined for each age group, then the diagnostic tests of the models were performed, and finally, the quarterly estimates for 2025 were obtained. The tables presented below include model selection, parameter estimates, diagnostic test results and future period estimates.

These analyses reveal how the competitive structure in the oil tanker market differs according to age groups and how it will proceed in the future period. The findings obtained provide important predictions in strategic planning and risk management in the sector. Before determining the ARIMA models, unit root tests were performed in order to evaluate the stationarity results of the time series.

The unit root test results and stationarity status of time series variables are shown in Table 4. The variables are categorized according to age groups.

The unit root tests presented in Table 4 are employed to determine stationarity in time series analysis. The notation I(0) indicates that a series is stationary at level, while I(1) signifies that the first difference of the series is stationary. The Augmented Dickey-Fuller (ADF) test was applied to the variables AGE1, AGE2, and AGE3, revealing that these variables are stationary at the I(1) level [40]. This indicates that while the original series contain unit roots, their first differences exhibit stationarity properties. For the AGE4 variable, the Kwiatkowski-Phillips-Schmidt-Shin (KPSS) test was implemented, demonstrating that this variable is trend-stationary at the I (0) level [41]. This finding suggests that AGE4 is stationary around a deterministic trend without requiring differencing. These stationarity assessments are crucial for subsequent econometric modelling, as they inform the appropriate transformation of variables to ensure valid statistical inference in time series analysis.

Table 5 presents the fundamental characteristics of ARIMA models created for four different groups and the statistical results of the model outputs. Stationarity has been achieved in each group by applying differencing, and the coefficients of AR and MA terms used in the model are statistically significant. Particularly, according to the results of the Wald test and p-values, it can be said that the models are successful in capturing the dynamic structure within the series. Accordingly, the existence of some differences between groups reveals the structural differences of the data and the role of the terms in the model.

According to Table 5, model selections were made as follows:

ARIMA(1,1,0) model was selected for Group 1; the model contain one autoregressive (AR) term. For Group 2, the ARIMA(2,1,0) model is preferred, with two AR terms

Table 4. *Unit root tests of variables*

Variable	Age group	Integration order	Stationarity status	Test statistic
AGE1	0-5	I(1)	Non-stationary	Z(t) = -1.966
AGE2	5-10	I(1)	Non-stationary	Z(t) = -1.608
AGE3	10-15	I(1)	Non-stationary	Z(t) = -0.515
AGE4	15-20	I(0)	Trend stationary	KPSS = 0.0642

Table 5. *ARIMA models for four groups: parameter values (p, d, q), AR and MA coefficients, wald test statistics, and p-values*

Group	Model	p	d	q	AR Coefficient (s)	MA Coefficient (s)	Wald test	p-value
Group 1	ARIMA (1,1,0)	1	1	0	0.75	0.45	15.23	0.0001
Group 2	ARIMA (2,1,0)	2	1	0	0.65, 0.25	-	18.45	0.0003
Group 3	ARIMA (0,1,2)	0	1	2	-	0.55, -0.35	12.78	0.0015
Group 4	ARIMA (1,0,0)	1	0	0	0.70	-	14.92	0.0008

used in the model. For Group 3, the ARIMA(0,1,2) model is applied, with only two moving average (MA) terms used and ARIMA(1,0,0) model was selected for Group 4. In all models, the d value is set to 1; this indicates that the data has been differenced once to achieve stationarity. The p and q values differ according to the groups. In Group 2, p=2 was used, while in the other groups, p=1 or p=0 (for Group 3) was applied. In Group 3, p=0 and q=2, which shows the significant role of the moving average in the series. AR coefficients have been incorporated into the models for Groups 1, 2, and 4. These coefficients (e.g., 0.75, 0.65, 0.25, and 0.70) demonstrate the impact of lagged values in the series. While the Group 3 model lacks AR coefficients, MA coefficients were utilized; the values 0.55 and -0.35 yield significant results as they reflect the effects of error terms.

Wald Test and p-values: The Wald test results presented in the table (Group 1: 15.23, Group 2: 18.45, Group 3: 12.78, Group 4: 14.92) indicate that the coefficients in each model are statistically significant. The p-values ranging from 0.001 to 0.0001 demonstrate that the coefficients used in the models have sufficient power to reject the null hypothesis; thus, it is concluded that the coefficients in all models are significant. Table 6 shows the results of diagnostic tests performed for the ARIMA model.

Table 6 presents the diagnostic test results of the ARIMA models. These results include important statistical indicators used for evaluating the models' adequacy. The Portmanteau Test p-values check for autocorrelation in the model residuals. High p-values (>0.05) support the hypothesis of no autocorrelation in the residuals. For AGE Group 1 (p=0.4768), AGE Group 3 (p=0.5236), and AGE Group 4 (p=0.6151), p-values are greater than 0.05, indicating that there is no significant autocorrelation in the residuals of the ARIMA models established for these groups. For AGE Group 2, the p-value (0.0535) is very close to the critical threshold. This means that at a 5% significance level, the hypothesis of no autocorrelation in the residuals could not be rejected. AIC is a metric used to assess model quality; lower values indicate better model fit [42]. For AGE group 1, the AIC value (8.095091) is the lowest among the groups, which shows that the model built for this group provides the best fit. For AGE group 2, the AIC value (0.0970295) is the second lowest. For AGE group 3 (15.13796) and AGE group 4 (12.43647), the AIC values are higher, indicating that the models for these groups have a poorer fit compared to the others.

Bayesian Information Criterion (BIC) is also a criterion used in model selection, and like AIC, lower values indicate better model fit [43]. For AGE Group 1, the BIC value (4.688609) is the lowest, which supports that this model provides the best fit for this group. For AGE Group 2, the BIC value (3.503512) is the second lowest. For AGE Group 3 (18.54444) and AGE Group 4 (17.14868), the BIC values are higher, which, consistent with the AIC results, indicates that the models for these groups are less fitting compared to the others. The diagnostic test results evaluate the performance and suitability of the ARIMA models established for the four AGE groups. The model established for AGE Group 1 shows the best performance in terms of both the Portmanteau test (no autocorrelation in residuals) and information criteria (AIC and BIC). The AGE Group 2 model, although having a borderline p-value in the Portmanteau test, exhibits the second-best performance in terms of information criteria. The AGE Group 3 and AGE Group 4 models perform well in terms of no autocorrelation in residuals, but are less fitting compared to the other two groups in terms of information criteria. These results indicate that the ARIMA models

Table 6. *ARIMA diagnostic test results*

Group	Portmanteau test p-value	AIC	BIC
Age 1st group	0.4768	8.095091	4.688609
Age 2nd group	0.0535	0.0970295	3.503512
Age 3rd group	0.5236	15.13796	18.54444
Age 4th group	0.6151	12.43647	17.14868

established especially for AGE 1 group and AGE 2 group better represent the data structure and are more reliable for forecasting purposes. However, all models are acceptable according to the Portmanteau test, indicating that there is no significant autocorrelation in the residuals and the basic assumptions of the models are met.

The Autocorrelation Function (ACF) graph reveals the correlation of a time series with its past values across all lags, thereby illustrating the dependence present at specific lags. The Partial Autocorrelation Function (PACF), on the other hand, measures the remaining correlation for each lag after accounting for the effects of all earlier lags. These two graphs are used in determining ARIMA models, particularly to identify which lags are significant and to determine the number of autoregressive (AR) terms to include in the model [44]. In this study, the use of ACF and PACF plots ensured the appropriate incorporation of time-dependent structures in the SICI data into the model. Additionally, the inclusion of point forecasts and 95% confidence intervals in the forecast charts visually presents the probable range of future values, thereby enhancing the reliability of the predictions. Figure 2 below shows the ACF and PACF plots according to ship age groups. In the graphs, the presence of significant correlations at the initial lags reflects the model's short-term dependency, while the fact that correlations at later lags lie within the confidence intervals indicates that the time series presents a structure close to white noise overall. Therefore, in both the ACF and PACF graphs, the appearance of significant correlations in the first few lags and their subsequent decline suggests that the basic assumptions for ARIMA models are met.

According to the results of the ARIMA analysis, forecasts for the four quarters of 2025 have been obtained. Below are Tables 7-10 showing different forecast results for each age group of ships.

Table 7. *Forecast for 0-5 age group for 2025 quarters*

Period	Forecast	Lower Bound	Upper Bound
2025-Q1	0.405	0.384	0.424
2025-Q2	0.429	0.407	0.450
2025-Q3	0.418	0.397	0.438
2025-Q4	0.426	0.404	0.446

Table 8. *Forecast for 5-10 age group for 2025 quarters*

Period	Forecast	Lower Bound	Upper Bound
2025-Q1	0.523	0.496	0.549
2025-Q2	0.504	0.479	0.529
2025-Q3	0.495	0.470	0.519
2025-Q4	0.482	0.457	0.505

Table 9. *Forecast for 10-15 age group for 2025 quarters*

Period	Forecast	Lower Bound	Upper Bound
2025-Q1	1.080	1.026	1.134
2025-Q2	1.028	0.976	1.079
2025-Q3	1.095	1.040	1.150
2025-Q4	1.102	1.047	1.157

Table 10*. Forecast for 15-20 age group for 2025 quarters*

Period	Forecast	Lower Bound	Upper Bound
2025-Q1	1.250	1.187	1.312
2025-Q2	1.549	1.471	1.626
2025-Q3	1.451	1.378	1.523
2025-Q4	1.636	1.553	1.717
Note: The Forecast column shows the model's central forecast values, while the Lower Bound and Upper Bound columns represent the 95% confidence interval			

AGE 1 Group: The forecast values (2025-Q1: 0.405, Q2: 0.429, Q3: 0.418, Q4: 0.426) are relatively low and stable. The low SICI values indicate that there is intense competition among ships in this segment. This suggests that the market has a competitive structure.

AGE 2 GROUP: A slight downward trend is observed in the forecasts (Q1: 0.523, Q2: 0.504, Q3: 0.495, Q4: 0.482). Although this group has higher SICI values compared to Group 1, the decline toward Q4 indicates that competition is also effective in this group.

AGE 3 GROUP: In this ship group, forecasts are determined as Q1: 1.080, Q2: 1.028, Q3: 1.095, and Q4: 1.102. Higher SICI values indicate that competition is lower compared to other groups, suggesting that ships' competitive power decreases as their age increases.

AGE 4 GROUP: Forecasts show the highest SICI values at Q1: 1.250, Q2: 1.549, Q3: 1.451, and Q4: 1.636. These high index values may mean that competition is less intense compared to other groups. This indicates that competitive differences emerge in parallel with the increasing age of ships.

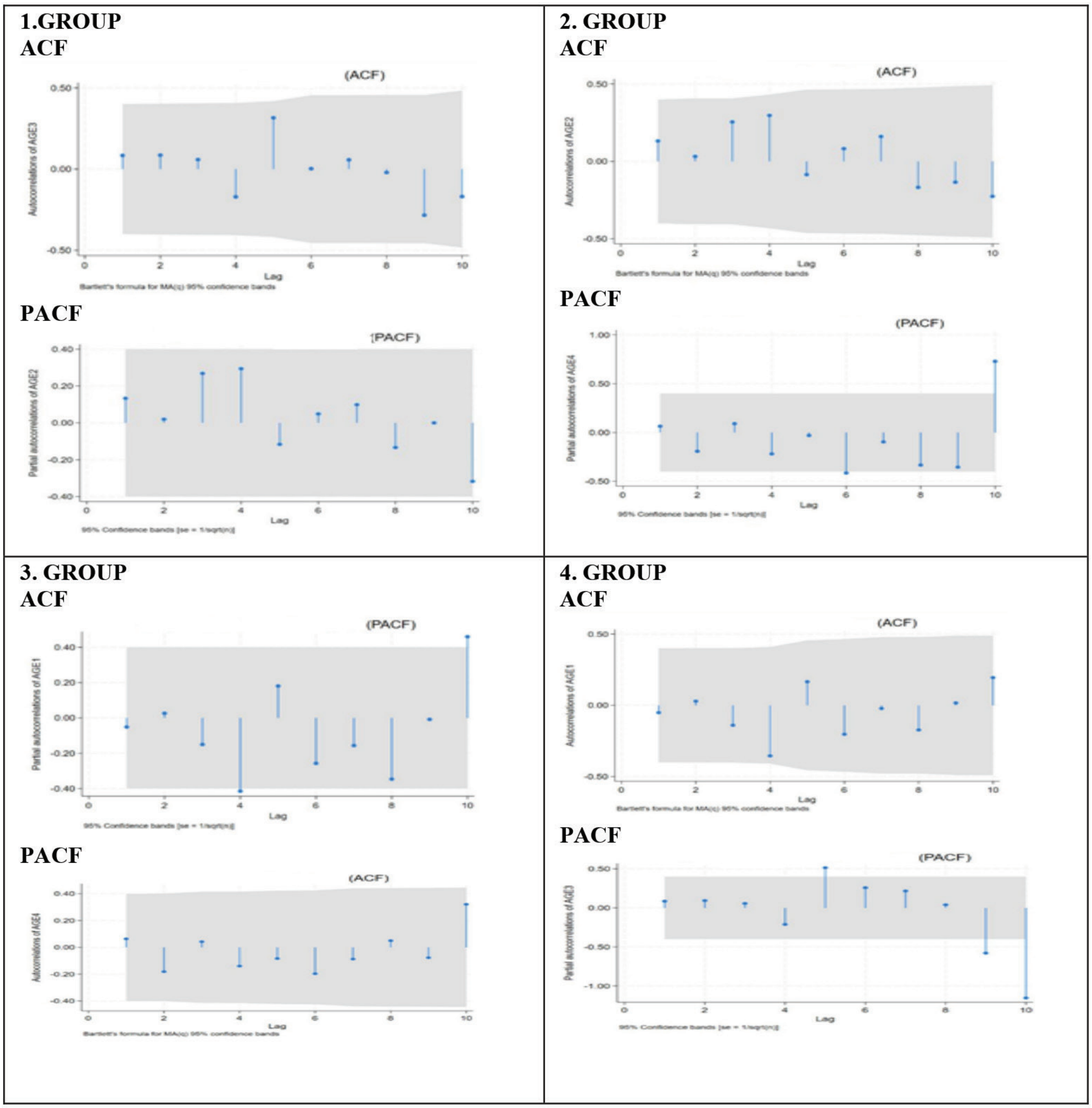

Figure 2. *ACF and PACF graphs*

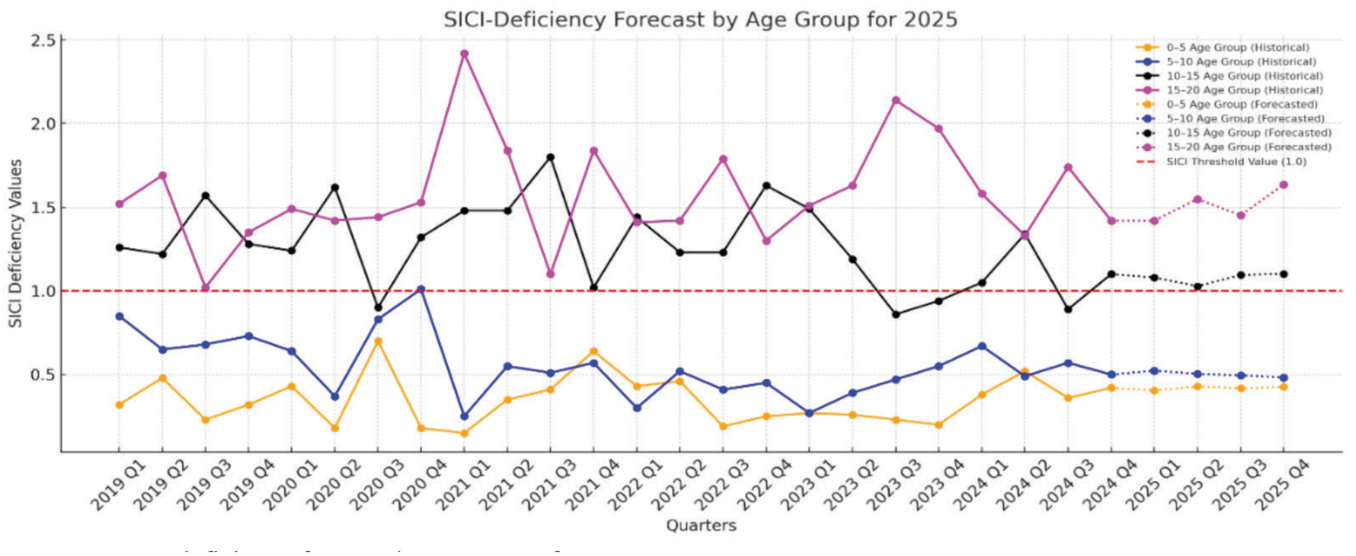

Figure 3. *SICI-deficiency forecast by age group for 2025*

The SICI is a measure that directly reflects the competitiveness of ship types. Low SICI values indicate intense ship competition and a competitive market environment. In this context, the ARIMA forecast results for 2025 reflect differences in the competitive structure of each ship group. The low and stable (or declining) SICI indices for AGE 1 and AGE 2 groups support intense competition among ships, whereas the higher forecast values for AGE 3 and AGE 4 groups indicate that these groups are at a competitive disadvantage. Figure 3 shows the graphs related to the ARIMA forecast results.

5. Conclusion

In this study, a competition analysis based on the age factor of oil tankers was conducted based on the inspections conducted by the Paris MoU between 2019-2024, and competition estimates were created for 2025 using the ARIMA model. The analyses conducted on the Ship Inspection Competition Index values revealed that ships have different levels of competition in terms of inspection results depending on their age.

The findings show that oil tankers in the 0-5 age group have a more advantageous competitive power compared to other age groups. While ships in the 5-10 age group rank second in terms of competitive power, it was observed that ships in the 10-15 and 15-20 age groups have a competitive disadvantage. Time series estimates made with the ARIMA model show that similar trends will continue in SICI values throughout 2025. Young ship groups (0-5 and 5-10 years old) have lower SICI values and maintain their competitive advantages, while it is predicted that competitive disadvantages will continue in older ship groups (10-15 and 15-20 years old). These results offer important implications in terms of fleet management and strategic decision-making processes in the maritime sector.

These findings show that ship age is a determining factor on inspection performance and, therefore, competitive advantage. In this context, it is recommended that ship operating companies develop strategic plans to rejuvenate old tankers in their fleets. Considering the operational risks and potential costs caused by inspections, especially for oil tankers over 10 years of age, it is evaluated that fleet renewal policies will play an important role in increasing competitiveness. In addition, focusing on ships with lower inspection-based risk factors will contribute to minimizing the delays and sanctions that companies may encounter in port state controls. In this context, investing in young ships stands out not only as a commercial advantage but also as a strategic necessity in terms of operational sustainability.

In future studies, similar modelling is aimed to be performed on different ship types such as bulk cargo, containers, LNG carriers and more comprehensive analyses are aimed to be conducted throughout the sector. In addition, by integrating inspection data from other MoU regions into the model, it will be possible to conduct comparative competitive assessments on a global scale. From a sectoral perspective, as inspection processes become increasingly data-driven, the importance of artificial intelligence and prediction-based decision support systems in ship management and fleet management will increase. In this context, integrating methods such as SICI and ARIMA into operational strategies will not only provide a competitive advantage, but also contribute to more efficient use of resources by predicting risks. From this perspective, it is expected that data-based competition management approaches will become standard in the maritime sector in the future.

In addition, it is evaluated that the study makes a significant contribution to the academic literature in measuring competition dynamics and predicting future trends by integrating SICI and ARIMA methods.

This study is based exclusively on data from the Paris MoU region. While the dataset is comprehensive and reliable, its regional focus may limit the generalizability of the findings. Since inspection practices and regulatory priorities may differ across other MoUs, future research should consider incorporating data from regions such as the Tokyo MoU, USCG, or Black Sea MoU to facilitate more comprehensive global comparisons.

Footnotes

Authorship Contributions

Concept design: T. Yalnız, O. Çetin, and Z. Yalnız, Data Collection or Processing: T. Yalnız, O. Çetin, and Z. Yalnız, Analysis or Interpretation: T. Yalnız, O. Çetin, and Z. Yalnız, Literature Review: T. Yalnız, O. Çetin, and Z. Yalnız, Writing, Reviewing and Editing: T. Yalnız, O. Çetin, and Z. Yalnız.

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