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COMPARATIVE ANALYSIS OF THE MERCHANT MARINE FLEETS OF THE ADRIATIC COUNTRIES

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Abstract. The Adriatic Sea is a strategically and economically important sea bordering Croatia, Italy, Albania, Slovenia, Bosnia and Herzegovina, and Montenegro. Throughout history, it has played a central role in trade and maritime activities and has become the basis for cultural and political interactions. In this study, the flagged commercial fleets of the countries bordering the Adriatic Sea are compared using hierarchical cluster analysis. The main objective of the study is to provide a comprehensive framework on the main characteristics of the SOLAS-subject merchant fleets owned by the countries in the Adriatic region. To this end, key parameters such as fleet size, vessel types, age distribution, and gross tonnage are analyzed. The findings contribute to the development of regional maritime policies by revealing the structural similarities and differences of the commercial fleets in the region. The results provide valuable insights for optimizing maritime transport strategies and strengthening regional cooperation.

Keywords: Maritime; Flag States; Adriatic Countries; Merchant Fleets.

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1. INTRODUCTION

Croatia, Slovenia, Italy, Bosnia-Herzegovina, Albania and Montenegro are the countries located in Adriatic area and the subject place plays a crucial role in global economy and strategic development. In historical perspectives, the area was in the heart of global trade and navigational activities. Hence, the cultural and political interactions within this area created global effects as well. Furthermore, the environmental issues are also concerning the countries located in Adriatic area. The dense navigational activities in the subject area are also affecting environmental problems. The ecological balances of the Adriatic are currently one of the hot topics for regulatory bodies. The navigational risks based on cruise traffic increase the significance of the region in terms of protection in terms of consensus in current literature (Dorigatti *et al*.,2023). Moreover, the environmental concerns are also a hot topic on the Adriatic coast due to heavy traffic and the strategic significance.

To improve the infrastructural conditions, innovative steps as well as navigational advancements in maritime industry, the clustering analysis methods may be effective to take further achievements. To consider the scope of this study, the factors localized in Adriatic area can be also evaluated with clustering framework.

Research question is understood to how the structural characteristics of the merchant fleets differ between the Adriatic countries and what does this means for regional maritime policy. It aims to analyzes has been carried out within this framework. The study adopts a comparative technique to achieve this objective.

Understanding the structural characteristics of merchant fleets is essential for assessing a country's maritime capacity, regulatory adequacy and compliance with international sustainability standards. Especially in regions such as the Adriatic, where geopolitical closeness is often contrasted with infrastructural inequality, cluster analysis provides a practical framework for comparative assessment.

2. LITERATURE REVIEW

Port investments and services provided during port operations that are influenced by investment capacity display that most of the global terminal services are operated through a limited number of companies and business partners (Notteboom and Rodrigue, 2012). Regarding the examination of fleet characteristics of the Adriatic countries, the ports with larger Twenty-Foot Equivalent Unit (TEU) capacities, such as those in Italy and Croatia, are more vulnerable to the effects of international terminal operators. This corporate density may serve as a restrictive factor regarding the development and international connections when it comes to situations of countries with small capacities.

The diversities within Adriatic countries in terms of fleet characteristics and flag state implementations may create some tensions in maritime trade, considering the maritime traffic density of the region. According to Vidas (2006), the status of the Adriatic Sea as a "Particularly Sensitive Sea Area" (PSSA) is a concrete result of the environmental crises due to navigational activities.

Referring to the studies where the vessels are compared in terms of age, flag state, and types of deficiencies, the fundamental reason for detentions is identified as the age of vessels and deficiencies in certifications. Specifically, the importance of Italian and Croatian port state controls is highlighted in the literature (Peričin *et al.*, 2024). The current study gives a meaningful and valuable context to evaluate the conditions of the regional fleet.

Sampson and Bloor (2007) criticized the existing regulatory frameworks due to the fragmentation and shortage of required sanctions in their evaluation of the maritime sector. Referring to this problem, they offer a "multi-layered inspection chain" which divides the responsibility not only among flag states but also the port state authorities, classification societies, and other parties such as stakeholders or charterers. To this end, strengthening the control processes during port visits and the transparent access to subject data, as agreed in the example of Paris MoU, plays a critical role for the Adriatic countries. Moreover, Sampson and Bloor (2007) emphasize the importance of regional foundations such as the European Union (EU) to meet International Maritime Organization (IMO) standards in an effective way. Considering the regions like the Adriatic Sea with complex borders and interactions, this kind of a model for management may be beneficial for both environmental factors in sensitive sea areas and the improvement of navigational standards for more sustainable solutions.

Similar to the IMO's 2020 sulphur cap, the global emission regulations in the European Green Deal focused on regional ports and owners.

Nearly 80% of global trade is conducted via maritime routes, in terms of data collected by the United Nations Conference on Trade and Development (UNCTAD). The contribution of the Adriatic fleet to this ratio is evaluated as small and medium scale. Referring to data received from the UNCTAD (2025), countries such as Croatia and Montenegro display a smaller effect when compared to the global fleet in

terms of gross tonnage and average fleet age. Thus, urgent action is required regarding the retrofitting activities for a more environmentally friendly fleet and safer maritime operations.

3. METHODOLOGY

This paper presents data obtained from ships flying the flags of countries bordering the Adriatic Sea. The data includes the number of ships, their gross tonnage, ship type, and age. These details will be analyzed comparatively in terms of both structural and statistical values.

SPSS package statistical program was and a two-step clustering method was employed utilized in this study. To be able to analyze various data types at the same time such as numerical and categorical, clustering techniques may be adopted. Moreover, this method is applicable for large data sets as well (Chiu *et al.*, 2001; IBM, 2021).

The Bayes Information Criterion (BIC) value and the Distance Ratio measure were employed to determine the number of clusters within the two-step clustering method. The role of BIC value is to diminish complexity of analysis and to provide simplest and best solution. Within this framework, the target of this method in SPSS is to determine clusters which have minimum BIC values. The working principle of the Distance Ratio is to measure the degree of difference between clusters. The higher the value of this measure, the more different the clusters are from each other (Schwarz, 1978).

The model automatically determines the optimal number of clusters based on the Bayesian Information Criterion (BIC), which balances model fit and complexity:

$$BIC = -2 \cdot \ln(L) + k \cdot \ln(n)$$

where is the model likelihood, the number of parameters, and the sample size (Schwarz, 1978). In addition, the Ratio of Distance Measures was used to evaluate cluster separation.

In this method, the data is automatically assigned to separate clusters. The extent to which these data belong to the relevant cluster or how compatible they are with that cluster is rated using the silhouette coefficient. This coefficient takes a value between 0 and 1. When the coefficient approaches 1, it means that the clusters are clearly separated, and when it approaches 0, it means that the clusters are complex (Kaufman & Rousseeuw, 2005).

The study draws on structured data obtained from the IMO GISIS database, covering 457 merchant vessels registered under Adriatic country flags. The variables analyzed include vessel age, gross tonnage, vessel type, and flag state. Each flag state was numerically encoded: 1 = Albania, 2 = Bosnia and Herzegovina, 3 = Croatia, 4 = Italy, and 5 = Montenegro.

4. FINDINGS

An analysis of 457 merchant vessels registered under Adriatic country flags revealed that the average fleet age is 23 years, while the average gross tonnage is approximately 24724 GT. The range of vessel ages, spanning from 0 to 67 years, indicates that fleets in the region comprise both newly built and significantly older vessels. Data on tonnage capacity and vessel type diversity highlight clear differences in transport capacity and operational structure among Adriatic countries. These structural differences were the primary determinants of inter-country divergence in the clustering analysis.

The auto-clustering output indicated that the structural differences among the merchant fleets of Adriatic countries are best represented by a five-cluster model. The minimization of the BIC value at five clusters confirmed this solution as the most balanced and explanatory. Additionally, the Ratio of Distance Measures (1.709) supports this as the optimal point of distinction.

These results demonstrate that the structural variables defined in the study (age, tonnage, diversity, and year of build) effectively group national fleets into five characteristic clusters. Introducing additional clusters would likely result in over-segmentation and a loss of interpretability; therefore, the five-cluster model is statistically valid and analytically sound.

Table 1. Descriptive Statistics (IMO GISIS, 2025).

	N	Minimum	Maximum	Mean	Std. Deviation
Age	457	0	67	23.04	14.972
Gross Tonnage	457	524	183858	24724.19	29090.614
Type	457	1	10	5.66	2.32
Flag	457	1	5	3.85	0.459
Valid N (listwise)	457				

Table 2. Auto Clustering.

Number of Clusters	Schwarz's Bayesian Criterion (BIC)	BIC Change[a]	Ratio of BIC Changes[b]	Ratio of Distance Measures[c]
1	1486192			
2	1137030	-349162	1	1.703
3	957275	-179755	0.515	1.601
4	867984	-89291	0.256	1.351
5	817832	-50153	0.144	1.709
6	813888	-3943	0.011	1.169
7	819348	5460	-0.016	1.328
8	838578	19230	-0.055	1.05
9	859814	21235	-0.061	1.366
10	891779	31966	-0.092	1.041
11	924911	33132	-0.095	1.388
12	965908	40997	-0.117	1.133
13	1009280	43371	-0.124	1.066
14	1053759	44480	-0.127	1.283
15	1101936	48176	-0.138	1.073

[a] Presents the changes relative to the previous cluster number. [b] Presents the change rates according to the change in the two-cluster solution. [c] Presents the ratio of distance measurements based on the calculation of the current number of clusters to the previous number of clusters.

The distribution of clusters shows that Adriatic countries exhibit significant yet proportionate diversity in their commercial fleet structures. The largest group, Cluster 3, represents fleets that are mixed but balanced in terms of age, diversity, and capacity. Conversely, Cluster 5, which comprises the smallest share, includes fleets with the most modern structural features. This suggests that some countries are represented by fewer but higher-quality vessels.

An assessment based on cluster centers shows that the fleet structures of Adriatic countries differ considerably in terms of age, capacity, and diversity. This confirms that such structures should be analyzed not only through a single metric like gross tonnage but also through multidimensional characteristics such as average fleet age and diversity. According to the findings:

- Cluster 1 includes the oldest fleets with the highest average age. These fleets are also characterized by low tonnage and limited vessel type variety, indicating a need for modernization.
- Cluster 2 comprises moderately aged fleets with some degree of diversity but limited gross tonnage. This cluster mainly includes vessels registered under the flags of small coastal states.
- Cluster 3 includes relatively young and highly diverse fleets. Vessels in this cluster have both high transport capacity and operational flexibility.
- Cluster 4 consists of specialized transport fleets that, despite having a lower average age, are focused on only a few vessel types. This suggests targeted investment in specific transport sectors.
- Cluster 5 includes fleets with the highest gross tonnage and the youngest average vessel age. These fleets typically belong to countries that are leaders and competitors in regional maritime transport.

Table 3. Centroids.

Cluster	Gross Tonnage Mean	Gross Tonnage Std. Deviation	Age Mean	Age Std. Deviation	Type Mean	Type Std. Deviation
1	6955.24	10827.476	45.3	9.171	6.68	1.367
2	11832.51	16591.474	21.77	13.989	5.27	2.39
3	23382.69	17580.874	18.94	6.973	7.11	0.994
4	16691.91	12964.524	15.79	6.228	2.4	0.812
5	81070.56	27531.064	9.44	6.662	6.61	1.857
Combined	24724.19	29090.614	23.04	14.972	5.66	2.32

Table 4. Flag States.

	Albania		Bosnia-Herzegovina		Croatia		Italy		Montenegro	
Cluster	Frequency	%	Frequency	%	Frequency	%	Frequency	%	Frequency	%
1	0	0.00	0	0.00	0	0.00	98	25.40	0	0.00
2	4	100.00	1	100.00	60	100.00	0	0,00	6	100.00
3	0	0.00	0	0.00	0	0.00	127	32.90	0	0.00
4	0	0.00	0	0.00	0	0.00	97	25.10	0	0.00
5	0	0.00	0	0.00	0	0.00	64	16.60	0	0.00
Combined	4	100.00	1	100.00	60	100.00	386	100.00	6	100.00

When evaluated at the national level, countries like Croatia, which possess higher capacity and younger fleets, were predominantly grouped in Cluster 5. Italy, on the other hand, appeared in Clusters 1 and 4 due to its combination of older and diverse fleet structures. In contrast, countries such as Bosnia and Herzegovina, Montenegro, and Albania (characterized by low diversity and capacity) were placed in the lower-performing clusters.

The level of cluster separation, with a silhouette coefficient of approximately 0.5, was found to be moderately successful, indicating clear internal consistency and inter-cluster distinction. This classification confirms that fleet structures among Adriatic countries differ not only in size but also in their underlying structural components.

5. DISCUSSION

The findings of this study also echo the concerns raised in recent international conference discussions, where the need to designate the Eastern Adriatic as a Particularly Sensitive Sea Area has gained traction. Dorigatti *et al.* (2023) notably emphasize that cruise ship routing in previously low-traffic regions has introduced unprecedented risks to fragile coastal zones. This operational shift, when combined with outdated or structurally weak merchant fleets in some Adriatic countries, presents a dual challenge: environmental vulnerability and insufficient fleet modernization. In this context, the present clustering analysis contributes a structural perspective that may complement ongoing regulatory considerations for the Eastern Adriatic, particularly in support of targeted protective measures under the IMO framework.

The ships were analyzed under 5 structural clusters, and as a result of the analysis, a grouping model was created that can be taken as a reference for maritime strategies to be implemented in the Adriatic region. The validity of the resulting model was checked using the BIC value and Distance Ratio criterion, and it was found to be supported. It is thought that this model will be guiding in the areas of creating a common maritime policy in the region, creating logistics connection points, and determining infrastructure and investment activities in the region.

The 5 clusters formed in the analysis also revealed that countries' maritime activities in the region are not similar, and their strategies in maritime activities may differ from country to country. While some countries prefer young fleets and large tonnage vessels, other countries continue to operate with old and small tonnage fleets. Thus, it can be seen that maritime activities do not follow the same line even in countries in the same region, and this situation will also be reflected in the competition levels of countries in the sector. The model reveals that while proximity unites these nations geographically, their maritime capacities diverge significantly. Croatia's presence in Cluster 5 signals strong modernization policies and greater logistical readiness. Italy's expansion into Clusters 1 and 4 reflects its strategic expertise.

These results support earlier claims in the literature about structural imbalances in the region. The impact of port state control regimes pointed out by Peričin *et al.* (2024) is reflected in the better structural outcomes of Croatia and Italy. Meanwhile, countries in Clusters 1 and 2 may need strategy support to encourage fleet renewal and compliance.

The benefit of clustering models is not limited to displaying differences from a structural way. Clustering methods are also beneficial for providing logical maritime policy regulations for the subject area. To evaluate flexibility, resilience and compatibility in terms of environmental effects, the analysis is not only based on fleet size or tonnages of the vessels but also vessel types and ages are considered as well.

The results of the study display that while comparing fleets, the gross tonnage is not enough as a solo factor. Age of vessels, types of vessels, as well as other vessel qualities as crucial as gross tonnage while creating a multifactor perspective. IMO regulations and standards aim to develop these policy strategies as well.

6. CONCLUSION

There are various differences among features such as gross tonnage and other structural features were identified regarding the analysis. Fleet sizes, vessel types, gross tonnages and vessel density of flag states were in the agenda of the subject study and the aim was to reveal the differences among these characteristics. The data on age, gross tonnage, and density of ship types included in the analysis in the study allowed us to evaluate the fleets not only in terms of tonnage size but also structurally.

The results of the analysis show that the identified structural characteristics of the countries' merchant fleets are grouped in a partially overlapping manner, even though they show variation across countries. The four structural variables used in the analysis show diversity across countries and form meaningful groups.

In sum, the outputs of the study revealed that the countries in the Adriatic region should review their fleet structures and evaluate the steps towards a younger and modernized fleet, and the countries with older fleets should provide strategies and financial support for the renewal of their fleets. Countries with large tonnage and various types of ships in the region may consider strengthening their logistics networks and investing in logistics bases in the region to make the most efficient use of their fleet capacities. Finally, it is predicted that this study, which reveals the fleet structures of the countries in the region, will benefit regional maritime cooperation and activities in the literature.

Conflict of interest: The authors have no conflicts of interest to declare.

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