Comparative Analysis of Port Traffic in Port Areas of the Colombian Atlantic Coast

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Abstract
In recent years, global port activity has experienced a significant increase, as reported by the Andean Community, indicating a 9.9% rise in worldwide port traffic in 2021 compared to the previous year. This surge has led to congestion issues at ports. However, contrary to this trend, Colombia has witnessed a decline in port activity over the last five years. This research aims to conduct a comparative study of port traffic along the Colombian Atlantic Coast, through which approximately 85% of the country's cargo is transported. The study employs statistical analysis using data science techniques to analyze cargo traffic patterns in the Port Zones (PZ) of this region. The results highlight key port PZs, such as Cartagena, Ciénaga, Golfo de Morrosquillo, and La Guajira, with coal, liquid bulk, and containerized cargo being predominant. Additionally, the study identifies export as the prevailing port activity. Examining the instability and negative variation in port activity in Colombia, significant statistical differences in cargo traffic are found in Ciénaga, La Guajira, and Golfo de Morrosquillo. The exports of coal and liquid bulk are identified as activities and cargo types potentially affecting port traffic along the Atlantic Coast.
Keywords:
Comparative Analysis, Port Traffic, Colombian Atlantic Coast, Port Zones, Statistical Analysis.

1. INTRODUCTION

Port activity has evolved into the most vital and significant economic factor globally. Studies indicate that nearly 90% of the world's economy relies on maritime transportation (Herrera, 2022). This reality has intensified competition among ports for cargo mobilization, prompting researchers to focus on this crucial sector of the global economy.
This emphasis on competitiveness has led ports to strive for greater competitiveness to establish a solid position in the port market. Competitiveness in ports has been extensively Studied using various methods. Some researchers, such as Başтuğ et al. (2022), employ survey methods and Analytic Hierarchy Process. Similarly, Kaliszewski (2020) studies port competitiveness factors using non-random quantitative primary social sampling methods.
Wahyuni and Hui (2020) explore key competitiveness variables by combining quantitative and qualitative analyses of focal group discussions. Competitiveness in ports has become a

significant area of research; however, few studies have focused on investigating port competitiveness through a comparative analysis using data science applied to port traffic.
Port traffic, defined by the Andean Community in its November 2022 annual report as "the operations of entry and exit or any movement of a vessel at sea, including the movement of inland navigation ships," has been steadily increasing in recent years. The report indicates a 0.1% increase in 2019 compared to 2018, a 2.7% increase in 2020 compared to 2019, and a 9.9% increase in 2021 compared to the previous year, confirming the growing trend in port transportation. However, data from this source reveals an instability with a decreasing trend in port traffic in Colombia over the past few years, as illustrated in Figuere No. 1, raising concerns and motivating this research.

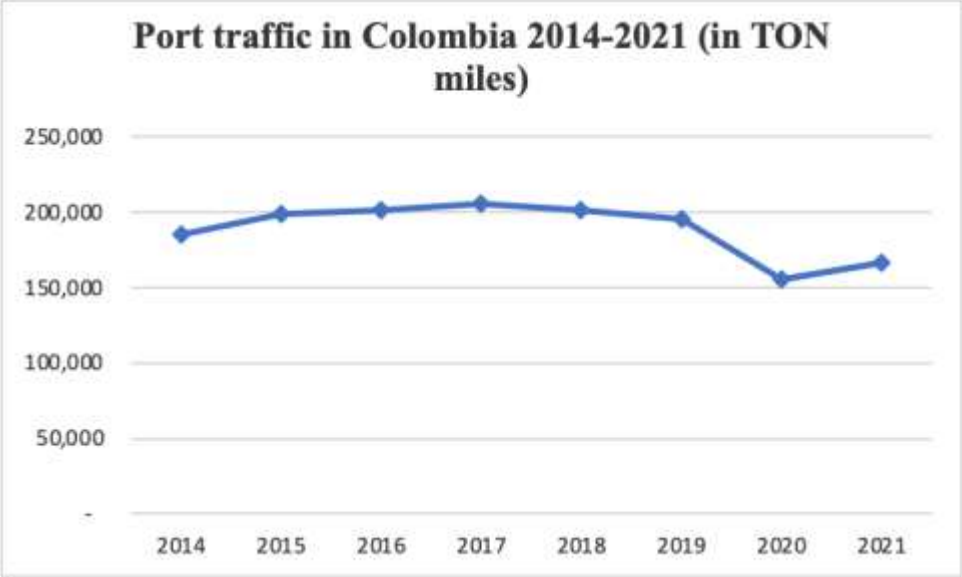

Figure. 1 Port Traffic in Colombia 2014-2021
Source: The author with data from the General Directorate of Port Captaincies and the NationalInstitute of Statistics of Bolivia, Superintendence of Transportation of Colombia, Sub Secretariat of Ports and Maritime and River Transportation of Ecuador, and National Port Authority of Peru. In original Spanish language

In Colombia, port traffic occurs through Port Zones (PZ), which are defined by the Law of the National Port System (LSPN) as:
"The PZ - The area of the national territory that includes the physical limits of the land assigned to the ports, including the areas delimited by physical perimeters on land, breakwaters, defenses, access channels, and pilot stations. In the case of ports that carry out operations through pipelines or buoys, it includes the operational area of the buoys and the pipelines up to the docks themselves. It includes Areas reserved for Port Development. Likewise, the port zone includes port development areas, ports, enclosures, and port terminals;likewise, the port zone includes infrastructures, facilities, multi-buoy terminals, whether public or private."
These PZs in Colombia are twelve, according to the Superintendence of Transportation of Colombia "Supertransporte," of which eight are on the Atlantic Ocean coast: La Guajira, Santa Marta, Ciénaga, Barranquilla, Cartagena, Golfo de Morrosquillo, PZ. Rio Magdalena, and San Andrés; three on the Pacific Ocean coast: Buenaventura, Turbo, and Tumaco, and the PZ of Barrancabermeja on the banks of the Magdalena River near the municipality of the same name. These PZs are further divided into Port Societies (SP), which can be public or private. The

National Infrastructure Agency (ANI) defines them as:
"They are anonymous societies, constituted with private, public, or mixed capital, whose corporate purpose will be the investment in the construction and maintenance of ports and their administration. Port companies may also provide loading and unloading services, storage in ports, and other services directly related to port activity."
On the other hand, the highest port traffic in Colombia is through the PZ of the Atlantic Coast (or Caribbean Coast) through their ports, approximately 85% according to data from Supertransporte (Figure No. 2). In this regard, Viloria (2006) points out that "the country has about 150 ports on its two coastlines, divided into twelve port zones, with the most active ones located on the Caribbean Coast." Therefore, this study will focus on analyzing the statistical data from these, with the main objective of conducting a comparative study of port traffic on the Colombian Atlantic Coast.

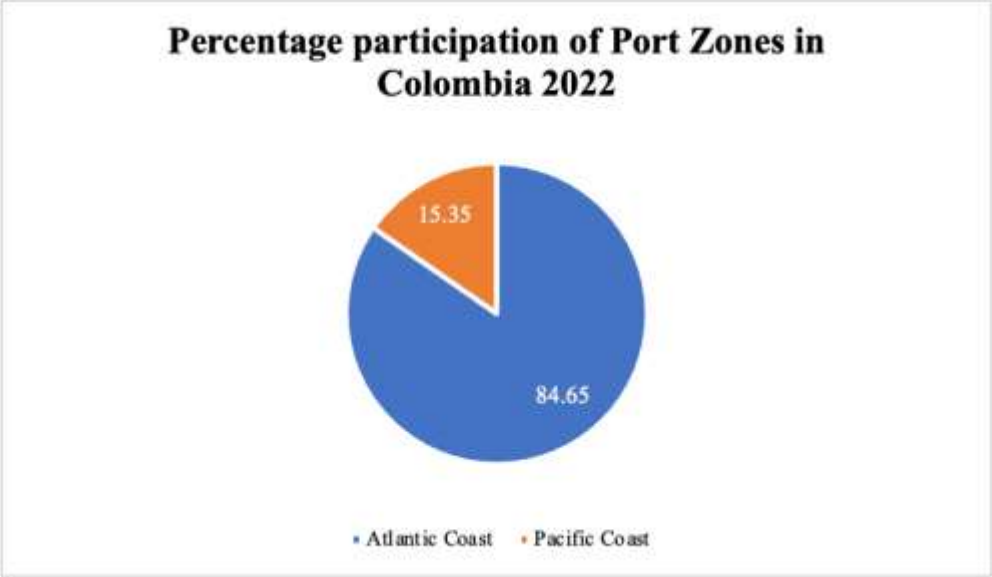

Figure No. 2: Percentage Participation of Port Zones in Colombia for the year 2022
Source: The author with data from the statistical report for the year 2022 by Supertransporte in Colombia. In original Spanish language

To conduct this research, the primary input will be data provided by the Superintendence of Transportation regarding port traffic in tons from the PZ located on the Colombian Atlantic Coast during the period from 2018 to 2022.
Aligned with the research objective, this investigation will employ an evaluation and statistical analysis using data science of port traffic in the Port Zones of the Colombian Atlantic Coast (La Guajira, Santa Marta, Ciénaga, Barranquilla, Cartagena, Golfo de Morrosquillo, PZ. Rio Magdalena, and San Andrés). The data is supplied by the Superintendence of Transportation of Colombia, categorizing this part of the study as a qualitative research model, which, according to Hernández-Sampieri (2018), falls under the quantitative approach, seeking to describe, explain, verify, and predict phenomena (causality), generate and test theories. This approach aligns seamlessly with the study's objectives.
Additionally, the research conducts a literature review to showcase the results and advantages of this type of study (comparative analysis) and its relevance in the port sector. The remainder of this study is organized as follows: 2 Literature Review, 3 Discussion and Results, 4 Conclusions and Future Work, and finally, Bibliographical References.

2. LITERATURE REVIEW

Numerous studies have utilized comparative analysis methodology to identify and study port-related situations or issues. For instance, Cho, C. H., Kim, B. I., & Hyun, J. H. (2010) introduced three dimensions of port service to measure customer satisfaction, loyalty, and reference intentions, using the ports of Incheon and Shanghai in China as their study focus.
Their aim was to provide strategic directions for both international ports by revealing customer perceptions and service quality recognition. Tang, L. S., et al (2022) employed comparative analysis to explore the hidden value of factors influencing the location of free trade port zones (FTPZ), specifically analyzing key location factors of the Shanghai and Ningbo-Zhoushan portsusing an econometric model. Liduma, D., Kairēna, A., & Priedens, M. (2015) used comparative analysis to study the competitiveness of the Liepaja port, considering the proximity of more developed ports, cargo turnover dynamics, and the technical capabilities of the port.
Zanne, M., & Borkowski, P. (2021) compared the ports of Koper in the Adriatic Sea and Gdansk in the Baltic Sea through the analysis of five elements: port management, port interior, business strategy, hinterland and connections, and port expansion plans. Yang, Y. C. (2009) conducted research from the perspective of inland ports, performing a comparative analysis to identify differences in the free trade zone (FTZ) policies between Taiwan and Korea in terms of objectives, areas, marketing, and incentives. Burke, C. M. (2015) conducted a comparative analysis of the largest western border port and the largest Midwest border port over the past 17 years.
Like these researchers, many have employed comparative analysis methodology to study different port-related issues. Zheng, S., & Negenborn, R. R. (2014) studied two types of port regulation modes, centralization, and decentralization, using principal-agent theory and dynamic game theory. Atencio, F. N. and Casseres, D. M. (2018) focused on comparing the performance of three well-known metaheuristics to determine the best docking sequence in terms of minimizing the total penalty cost for assigning a fixed number of ships to a bulk port located in Santa Marta (Colombia). Ha, M. H. and Yang, Z. (2017) analyzed the accuracy of Port Performance Indicators (PPI) and the arguments about performance measurement results.
In conclusion, many authors have used this methodology to study port issues, yielding significant findings that have contributed to understanding and solving these problems. However, few have focused on studying port traffic and its implications for competitiveness development. Therefore, this study is focused on that aspect, utilizing statistical analysis in the data processing procedure with the support of the statistical software SPSS Statistics.

3. DISCUSSION AND RESULTS

In recent years, Colombian ports have become the most predominant and influential economic sector in the country. As mentioned earlier, a high percentage of national and international trademoves through this sector. However, there has been an instability tending towards a decrease in the country's port traffic in recent years. The Colombian Atlantic Coast, in particular, transports approximately 85% of national and international trade through its PZ. Similar to thenational territory, port traffic in the PZ in this region has been affected (as shown in Figure No.3). All of this, coupled with the availability of port traffic information in

Colombia provided by Supertransporte, has motivated the comparative study with these PZs (La Guajira, Santa Marta, Ciénaga, Barranquilla, Cartagena, Golfo de Morrosquillo, PZ Rio Magdalena, and San Andrés).

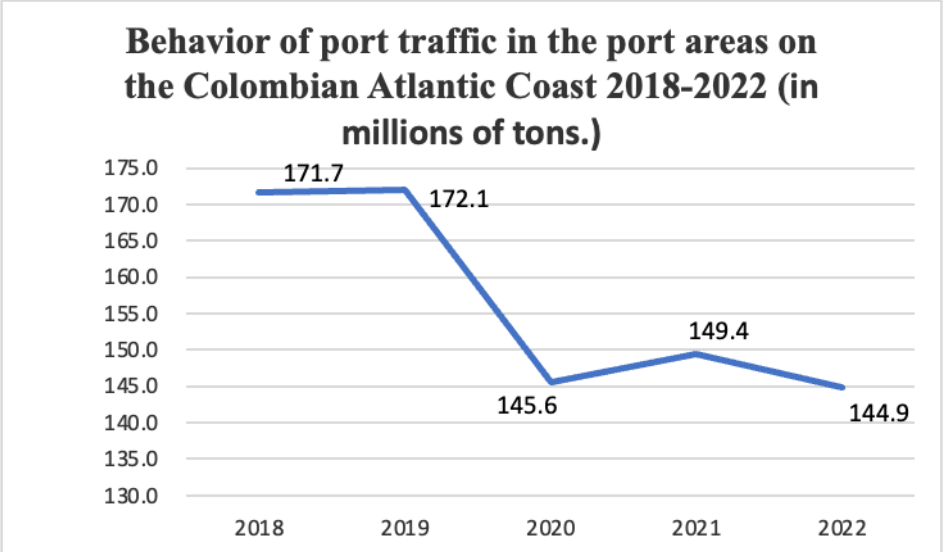

Figure No. 3: Behavior of Port Traffic in the Port Zones of the Colombian Atlantic Coast 2018- 2022

Source: The author with data from the statistical report by Supertransporte in Colombia for the years 2018-2022. In original Spanish language

Port Zones (PZ) and their Characteristics

Barranquilla PZ: Located 22 km from the mouth of the Magdalena River, it comprises, according to Supertransporte, 10 PSs: Atunamar Ltda, Barranquilla Internacional Terminal Company S.A, Compañía de Puertos Asociados S.A, Palermo PS S.A, PS Michellmar S.A, PS Monómeros Colombo Venezolanos S.A, PS Regional Barranquilla S.A, PS Riverport S.A, and Volpak Colombia S.A. This PZ handles containerized cargo, bulk coal, general cargo, liquid bulk, and solid bulk other than coal. Traffic is generated by coastal disembarkation, coastal embarkation, exports, imports, inland embarkation, inland disembarkation, onboard

mobilizations, transshipment, international transit, and transitory operations.

Figure No.4: Barranquilla Port Zone (Asoportuaria (n.d)).

Cartagena PZ: Located facing the Caribbean Sea in the northwest of Colombia, in the city of Cartagena, with an area of 82 km², it is the most important PZ in the country, mobilizing

around 247 million tons of cargo by the year 2022 (Supertransporte 2023). It has 24 PS (Port Services): Algrane S.A, Atunamar Ltda, Compañía de Puertos Asociados S.A, Coremar Shorebase S.A, Ecopetrol S.A, Nueva PS zona Atlántica S.A, Oiltanking Colombia S.A, Puerto Buenavista S.A, Puerto de Mamonal S.A, Puerto Caribe PS S.A, Refinería de Cartagena S.A.S, Las PS Bavaria S.A, Del Dique S.A, Dexton S.A, El Cayao S.A, Olefinas y derivados S.A, Puerto Bahía S.A, Regional de Cartagena S.A, Terminal de Ifos S.A, Transmarsyp S.A, terminal de contenedores de Cartagena S.A, Vopak Colombia S.A, Zona franca Argos S.A.S. Through these, containerized cargo, bulk coal, general cargo, liquid bulk, and solid bulk other than coal are mobilized. The ports handle coastal unloading, coastal loading, exports, imports, embarked river traffic, on-board mobilizations, transshipment, and international transit.

Figure No.5: Cartagena Port Zone, (Dlca.loncluster (n.d))

Ciénaga PZ: Located in the city of Ciénaga, 22 km south of the city of Santa Marta in the department of Magdalena. It is a Port Zone where the predominant cargo is coal from the Cesar department. It is comprised of two Port Societies (SP): Puerto Nuevo Port Society and American Port Company Inc. These ports are exclusive to the coal companies Drummond Ltda. and Prodeco, respectively. The type of cargo it transports is bulk coal, and its port traffic is predominantly mineral export.

Figure 6: Ciénaga Port Zone, (Google Maps (n.d)).

Golfo de Morrosquillo PZ: Located in the northwest of the country in the department of Sucre, it is characterized by the transportation of oil and products for the cement industry. It has three port societies: Cenit Transporte y Logística de Hidrocarburos S.A.S, Compañía de Puertos Asociados S.A, and Oleoducto Central S.A. The type of cargo it moves from its ports includes bulk coal, containers, general cargo, liquid bulk, and solid bulk other than coal. Its traffic is based on export, import, and coastal embarkation.

Figure 7: Golfo de Morrosquillo PZ Port Zone, (Google Maps (n.d)).

La Guajira PZ: Located on the Guajira Peninsula in the municipality of Uribia, north of Colombia, 166 km from the city of Riohacha. The predominant cargo transported through its ports is coal. It is comprised of three Port Societies (SP): Cerrejón Zona Norte S.A, Puerto Brisa S.A, and PS de la Península S.A. The type of cargo its ports handle includes bulk coal, containers, general cargo, liquid bulk, and solid bulk other than coal. Port traffic is mainly associated with export and import operations.

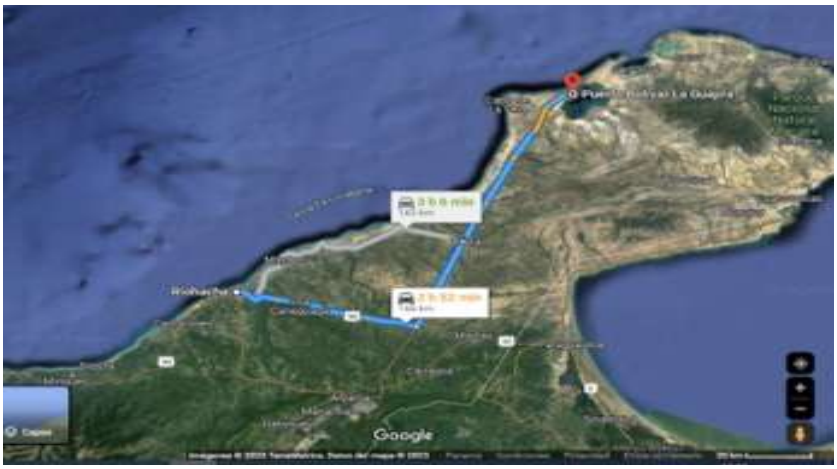

Figure 8: La Guajira Port Zone, (Google Maps (n.d)).

San Andrés PZ: Located in the northwest of San Andrés Island in the northwest Atlantic Ocean of Colombia at coordinates 12° 35' 37" to 14° 42' latitude north and 81° 40' 49" to 81° 43' 13" longitude west. It is comprised of two PS: Nueva PS Zona Atlántica S.A and San Andrés Port Society S.A. The type of cargo its ports move includes containers, general cargo, liquid bulk, and solid bulk other than coal. Its port traffic includes coastal embarkation, coastal disembarkation, import, export, transshipment, international transit, and transitory operations.

Figure 9: San Andrés Port Zone, (Facebook (n.d)).

Santa Marta PZ: Located at the extreme northwest of the city of Santa Marta, bordered to the north by the hills of San Martín and to the west by Cerro Ancón and the Ensenada de Taganguilla; it consists of two PSs, Cenit transporte y logística de hidrocarburos S.A.S and the PS of Santa Marta. The types of cargo it transports include coal, containers, general cargo, liquid bulk, and solid bulk other than coal. The port traffic involves importation, exports, transshipment, coastal unloading, and coastal loading.

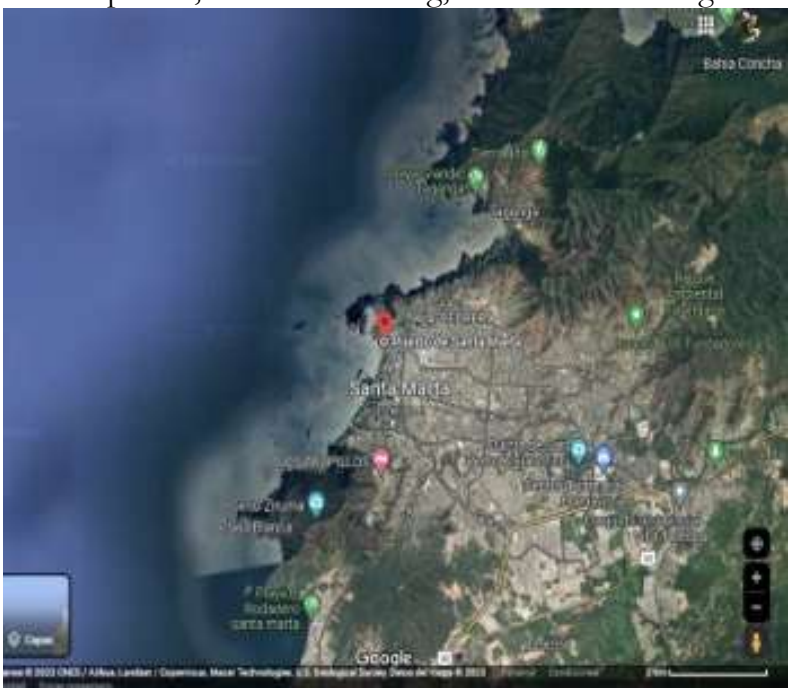

Figure 10: Santa Marta Port Zone, (Google Maps (n.d)).

Rio Magdalena PZ: This port zone is located on the Magdalena River at kilometer 3 on the road from Malambo to Sabana Grande in the department of Atlántico. It is comprised of two PSs: Puerto Pimsa S.A and PS La Gloria de Colombia S.A. The ports in thiszone handle bulk cargo, liquid bulk, and solid bulk other than coal. Port traffic is predominantly associated with coastal embarkation, coastal disembarkation, export, import, river disembarkation, and river embarkation.

Figure 11: Rio Magdalena Port Zone, (Gogle Maps(n.d)).

The statistical data regarding the port traffic of these Port Zones (ZP) for the years between 2021 and 2022 show a decreasing trend or negative variation of -3.8% according to the port traffic statistical bulletin in Colombia (Supertransporte 2023, p.5). Therefore, this section will conduct a statistical analysis of the cargo movement in these ZPs, seeking patterns to analyze the phenomenon.

The analysis begins by examining the behavior of port traffic in these PZs to determine their market participation and trends from 2018 to 2022. As shown in Figure No. 4, the participation in the Cartagena and Ciénaga PZs is the most significant, registering 27.15% and 24.74% respectively. Additionally, the Golfo de Morrosquillo and Puerto Bolívar PZs stand out with 18.54% and 14.92% respectively, making them the PZs with the highest cargo mobilization in tons on the Atlantic Coast over the last five years.

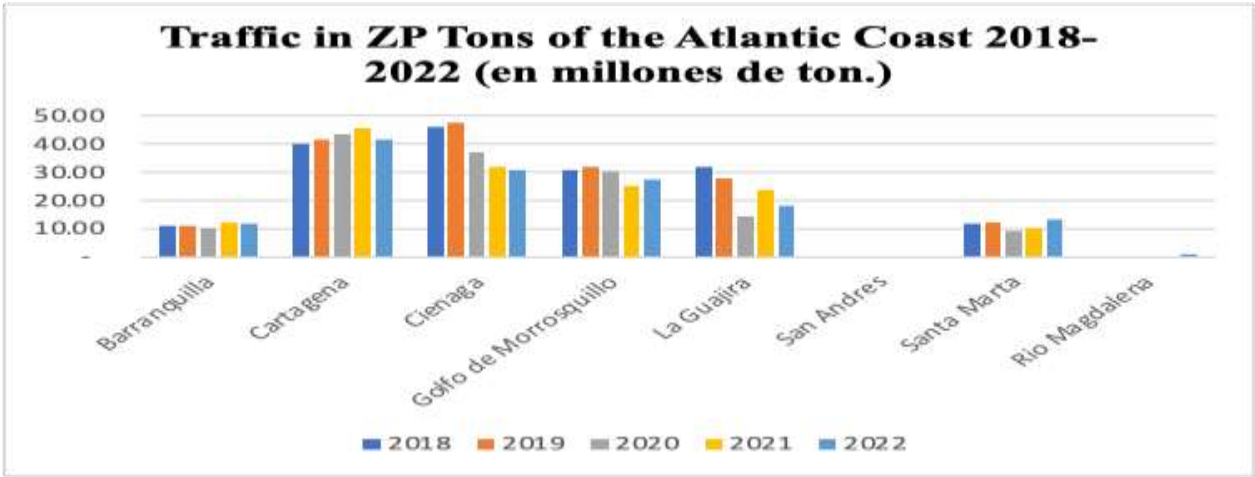

Figure 12: Port Traffic in the PZ of the Colombian Atlantic Coast 2018-2022.
Source: The author with data from the statistical report of Supertransporte in Colombia 2018-2022. In original Spanish language

To gain a deeper understanding of the port traffic in these PZs, the calculation of the percentage variation in the participation of cargo movement for each analyzed PZ was performed. It was determined that the PZs of Barranquilla and Cartagena remain stable, while Ciénaga and Golfo de Morrosquillo show a certain percentage of loss in participation, but with no significant percentage variations in cargo traffic on the Colombian Atlantic Coast. However, the PZs La Guajira, San Andrés, Rio Magdalena, and even Santa Marta have experienced instability in participation. Notably, the Rio Magdalena PZ stands out, showing significant growth in port traffic during the analyzed period, with an increase of approximately 300% in its participation in the last period. Despite this growth, it has not yet become a representative PZ on the Colombian Atlantic Coast, as depicted in Figure No. 13.

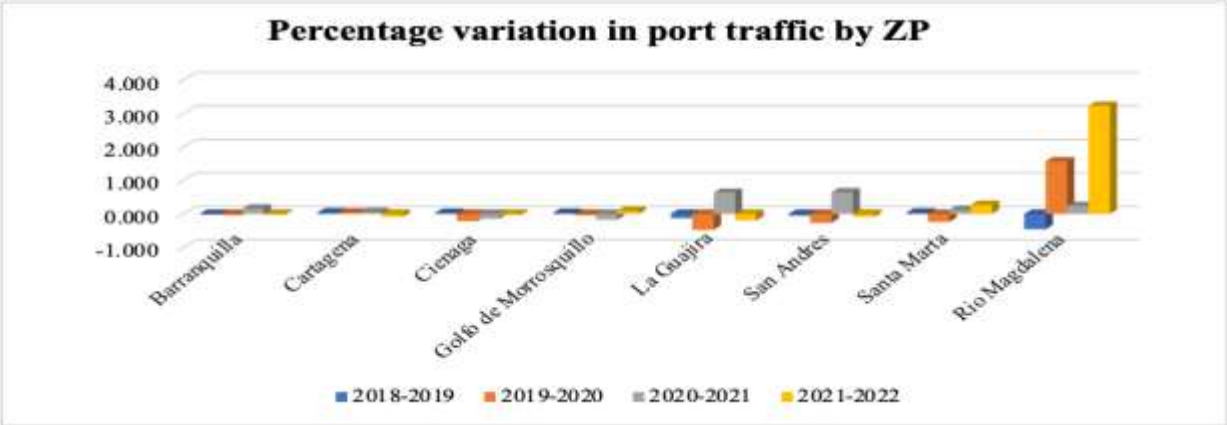

Figure 13: Percentage Variation in Port Traffic in the PZ of the Colombian Atlantic Coast 2018- 2022.
Source: The author with data from the statistical report of Supertransporte in Colombia 2018-2022. In original Spanish language

Analyzing the results of the percentage variation in the participation of cargo distribution for these PZs, with the aim of observing their behavior, it was found that the PZs that have been losing space in the port market of the Atlantic Coast, negatively affecting the port traffic statisticsof this region and the country, as indicated at the beginning of this research, are Ciénaga and La Guajira PZs (as shown in Table No. 1 and Figure No. 14). These PZs show negative variations inthe last five years of -5.48% and -5.45%, respectively. This could be

interpreted as a decrease in coal production in the mines of La Guajira and Cesar. Considering that these are transport ports where coal exploitation prevails through their PSs, some exclusively dedicated to coal export (PS Puerto Nuevo S.A., American Port Company Inc, and Cerrejon Zona Norte S.A.), which, in turn, significantly impacts the country's port traffic, as these are representative ports in port traffic. However, the PZs of Cartagena, Santa Marta, and Barranquilla have a positive percentage variation in the participation of port traffic in the region over the last five years, with 5.50%, 2.23%, and 1.75%, respectively. This indicates that they are gaining space in the consolidated port traffic on the Colombian Atlantic Coast. In the other PZs, the percentage variation is positive but very close to 0%, which can be interpreted as the conservation of the participation in port traffic on the Atlantic Coast.

Port Zones	% Variation
Barranquilla	1,75
Cartagena	5,50
Cienaga	-5,48
Golfo de Morrosquillo	0,91
La Guajira	-5,45
San Andrés	0,04
Santa Marta	2,23
Rio Magdalena	0,51

Table No. 1: Percentage Variation in the Participation of Port Traffic by ZP on the Colombian Atlantic Coast 2018-2022.

Source: The author with data from the statistical report of Supertransporte in Colombia 2018-2022

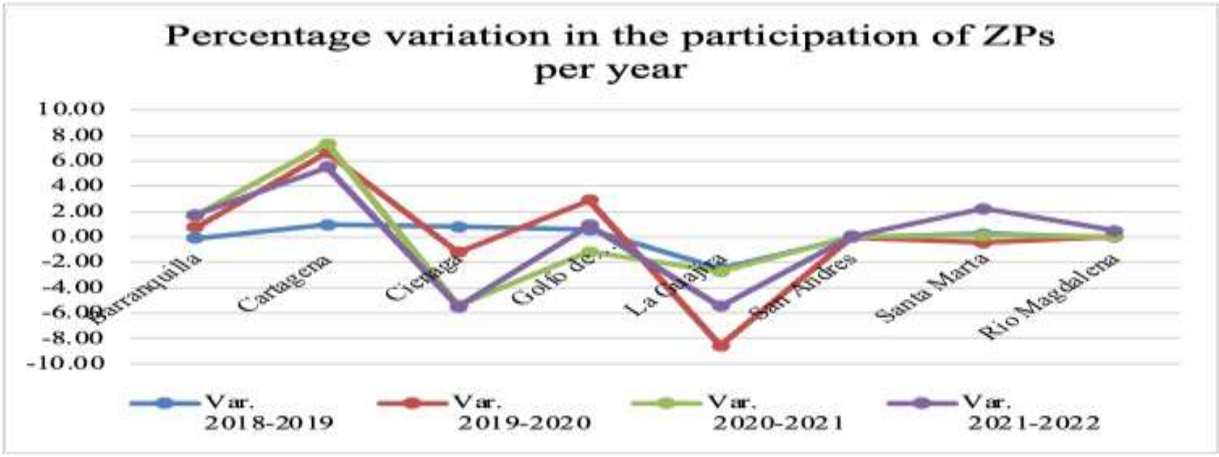

Figure 14: Percentage Variation in the Participation of the Colombian Atlantic Coast ZP 2018-2022.

Source: The author with data from the statistical report of Supertransporte in Colombia 2018-2022. In original Spanish language

When analyzing the percentage variation in port traffic 2018-2022 (Table No. 2), it was found that Ciénaga, La Guajira, and Golfo de Morrosquillo show a decrease in port traffic of 32.9%, 40.4%, and 11.3%, respectively. On the other hand, Barranquilla, Cartagena, San Andrés, and Santa Marta have had an increase in port traffic of 7.3%, 4.4%, 3.2%, and 12.0%, respectively. Notably, the Rio Magdalena ZP stands out with significant growth of 628.4%. Likewise, it can be observed that the decrease in port traffic in the ZPs of the Atlantic Coast is 15.6%.

	Years	% Variation

Port Zones	**2018**	**2022**	
Barranquilla	11.058.917	11.863.487	7,3
Cartagena	39.899.369	41.641.778	4,4
Cienaga	46.006.832	30.880.644	-32,9
Golfo de Morrosquillo	30.743.838	27.269.681	-11,3
La Guajira	31.862.085	18.997.891	-40,4
San Andrés	343.176	354.046	3,2
Santa Marta	11.691.247	13.094.314	12,0
Rio Magdalena	113.872	829.428	628,4
Total	**171.719.336**	**144.931.269**	**15,6**

Table No. 2: Percentage Variation in Port Traffic by ZP on the Colombian Atlantic Coast2018-2022.
Source: The author with data from the statistical report of Supertransporte in Colombia 2018-2022.

While the above is important, it does not provide sufficient evidence to indicate the causes of the decrease in port traffic on the Atlantic Coast and in Colombia.
To delve a little further into the phenomenon, a statistical analysis of the type of cargo transported through these ZPs was conducted. It was found that the predominant cargo in the Cartagena PZ is containerized cargo, while in the Ciénaga and La Guajira PZs, it is bulk coal. Golfo de Morrosquillo and Santa Marta specialize in liquid bulk, while in the Barranquilla and San Andrés PZs, there is no predominant cargo. Additionally, there are PZs like Ciénaga and Puerto Bolívar where non-coal port activity is minimal or almost nonexistent. However, between the two, they represent about 40% of the cargo movement on the Colombian Atlantic Coast. Similarly, Cartagena represents 27% of this port traffic in the last 5 years (2018-2022). In thesame vein, Golfo de Morrosquillo is the PZ with the highest movement of liquid bulk in this region of the country.

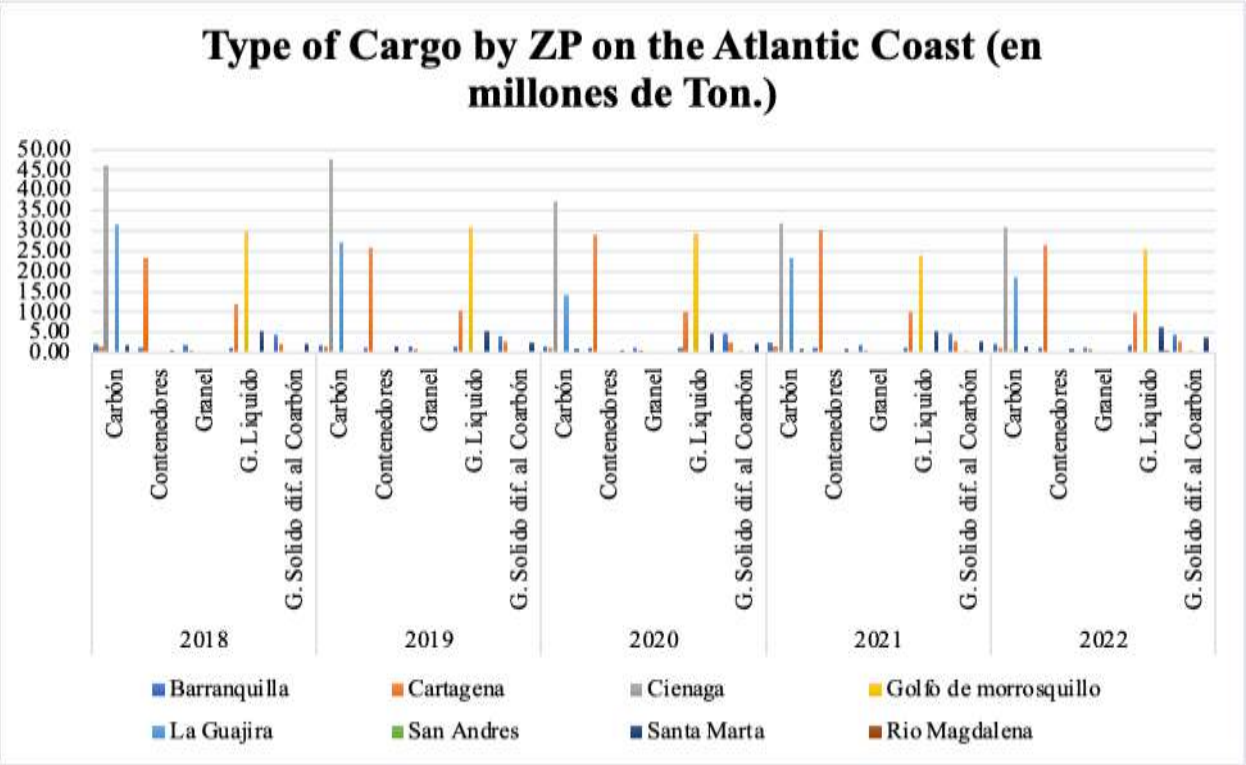

Figure 15: Types of loads by PZ on the Atlantic Coast 2018-2022.
Source: The author with data from the statistical report of Supertransporte in Colombia 2018-2022. In original Spanish language

In terms of the port activity of these PZs, it was evident that Cartagena is indeed the most important in port traffic in this region of the country and relies on its strength in the export, import, and transshipment of cargo. However, concerning exports, the strongest PZs are Ciénaga, Golfo de Morrosquíllo, and La Guajira, respectively. Meanwhile, the PZs of Barranquilla and Santa Marta excel in imports.

Year	Port Activity	Port Zones							
		Barranquilla	Cartagena	Ciénaga	Golfo de Morrosquillo	Puerto Bolívar	San Andrés	Santa Marta	Rio Magdalena
2018	Export	3.124.956	11.018.100	46.006.832	30.127.925	31.428.433	4.369	3.894.052	13.704
	Import	7.574.797	9.303.778	-	563.281	433.652	109.308	6.418.736	24.276
	Transshipment	-	17.136.338	-	-	-	-	15.947	-
	Internal Transit	7.271	293.106	-	-	-	293	-	-
	River	46.767	6.404	-	-	-	-	-	747
	Cabotage	299.802	2.124.840	-	52.632	-	229.	1.362.512	-

Year	Port Activity	Port Zones							
		Barranquilla	Cartagena	Ciénaga	Golfo de Morrosquillo	Puerto Bolívar	San Andrés	Santa Marta	Rio Magdalena
							064		
	Onboard Movement	-	-	-	-	-	-	-	-
	Transient	5.324	16.803	-	-	-	142	-	75.146
2019	Export	2.796.333	11.310.037	47.495.852	31.181.537	27.286.397	3.862	3.179.077	13.297
	Import	7.704.578	9.390.041	-	610.181	428.929	95.856	8.426.767	19.078
	Transshipment	533	19.256.538	-	-	-	-	40.420	-
	Internal Transit	9.560	254.300	-	-	-	341	-	-
	River	108.039	7.364	-	-	-	-	-	-
	Cabotage	255.327	1.443.014	-	-	-	224.219	506.806	29.496
	Onboard Movement	4.024	277	-	-	-	-	-	-
	Transient	13.588	14.563	-	-	-	-	-	-
2020	Export	3.471.248	10.881.517	37.233.999	29.282.115	14.325.892	4.469	1.574.314	-
	Import	6.524.319	8.389.907	-	867.357	172.767	61.982	6.173.804	33.441
	Transshipment	2.382	20.491.731	-	-	-	-	19.865	-
	Internal Transit	1.915	274.999	-	-	-	-	-	-
	River	164.861	103	-	-	-	-	-	-
	Cabotage						171.	1.457.	125.43

Year	Port Activity	Port Zones							
		Barranquilla	Cartagena	Ciénaga	Golfo de Morrosquillo	Puerto Bolívar	San Andrés	Santa Marta	Rio Magdalena
		287.176	3.464.295	-	138.731	-	152	906	3
	Onboard Movement	-	-	-	-	-	-	-	-
	Transient	15.878	-	-	-	-	-	-	-
2021	Export	4.205.529	11.327.906	31.997.416	19.964.135	23.369.267	5.883	1.441.397	-
	Import	7.540.624	10.581.337	-	5.053.011	289.483	128.484	7.150.141	35.999
	Transshipment	4.279	19.933.490	-	-	-	-	7.059	-
	Internal Transit	4.876	317.692	-	-	-	201	-	-
	River	89.184	2.541	-	-	-	-	-	-
	Cabotage	281.797	3.578.777	-	-	-	255.885	1.725.725	160.185
	Onboard Movement	12.376	4.962	-	-	-	-	-	-
	Transient	4.463	4.517	-	-	-	88	-	-
2022	Export	3.924.653	10.613.251	30.880.644	25.159.189	18.652.624	6.111	2.541.075	-
	Import	7.136.491	10.219.521	-	1.245.478	345.267	97.770	9.236.092	17.728
	Transshipment	58.794	16.815.421	-	-	-	-	15.972	-
	Internal Transit	49.025	72.015	-	-	-	20	-	-
	River	193.570	4.217	-	-	-	-	-	477.42

Year	Port Activity	Port Zones							
		Barranquilla	Cartagena	Ciénaga	Golfo de Morrosquillo	Puerto Bolívar	San Andrés	Santa Marta	Rio Magdalena
									6
	Cabotage	496.351	3.916.393	-	865.014	-	250.135	1.301.175	112.776
	Onboard Movement	-	-	-	-	-	-	-	-
	Transient	4.603	960	-	-	-	10	-	-

Table No.3: Port Activity in the Colombian Atlantic Coast Port Zones (ZP) 2018-2022.
Source: The author with data from the statistical report of Supertransporte in Colombia 2018-2022.

In order to confirm some results regarding the influence on participation and port traffic, we formulated a null hypothesis H_0 stating that the type of cargo is decisive in the port traffic of each PZ, and an alternative hypothesis H_i that the type of cargo is not decisive in the port traffic of each PZ. The following formulas were used for the calculations, with a confidence level of 95%.

A correlation analysis was carried out to study the possible influence, for example, between the variables of tons mobilized and the most significant type of cargo in each PZ according to their percentage participation. For this purpose, the PZ with the greatest impact or participation in port traffic on the Colombian Atlantic Coast was taken into account, using the following equation:

$$r_{xy} = \frac{\sum[(x_i - \bar{x}) * (y_i - \bar{y})]}{\sqrt{\sum(x_i - \bar{x})^2 * \sum(y_i - \bar{y})^2}} \quad (1)$$

Where the variable "x" represents the type of cargo in each analyzed PZ, while the variable "y" represents the tons mobilized. Also, "$\bar{x}$" and "$\bar{y}$" represent the averages in each of them, respectively.

The results of the calculations for each PZ are shown in Table No.4:

Port Zones	Type of load	Correlation Coefficient (Pearson)
Cartagena	Contenedor	0,818
Ciénaga	Carbón	0,995
La Guajira	Carbón	1,000
Golfo de Morrosquillo	Granel Liquido	0,991
Santa Marta	Granel Liquido	0,404

Table No. 4 Pearson ZP evaluation coefficient according to predominant load 2018-2022
Source: The author with data from the Supetranspote statistical report in Colombia 2018-2022

In order to test these results using Pearson correlation and considering that we are working with time-series data (in the period 2018-2022) applying formulas (2) and (3) with delays or lags (k) (initially for k=0), calculations were carried out for a time-series correlation using software, yielding the results shown in Table No.5.

$$r_{xy(-k)} = \frac{\sum[(x_t - \bar{x}) * (y_{t+k} - \bar{y})]}{N\sqrt{\sum(x_t - \bar{x})^2 * \sum(y_t - \bar{y})^2}}$$

(2)

$$r_{xy(-k)} = \frac{\sum[(x_{t+k} - \bar{x}) * (y_t -$$

In these formulas:

represents the value of a data point at time t−k for the independent stationary series.

x_t, x_{t+k}

y_t, y_{t+k}, represents the value of a data point at time, t and k the time data of the stationary dependent series

S_y and S_x, represents the standard deviation of the series y_t and x_t respectively.

N is the number of data pairs in the series y_t and x_t.

$\bar{y}$ and $\bar{x}$ means of the series of y_t and x_t, respectively.

k is the lag or delaybetween an observation at time t and another at a subsequent or previous time.

Port Zones	Type of load	Correlation Coefficient (Pearson)	Correlation Coefficient (time series)	Standard Error
Cartagena	Contenedor	0,818	0,818	0,129
Ciénaga	Carbón	0,995	0,995	0,129
La Guajira	Carbón	1,000	1,000	0,129
Golfo de Morrosquillo	Granel Liquido	0,991	0,991	0,129
Santa Marta	Granel Liquido	0,404	0,404	0,129

Table No.5 Pearson Correlation Coefficient and Time Series According to Predominant Cargo in Each ZP 2018-2022

Source: The author with data from the statistical report of Supetransporte in Colombia 2018-2022.

Table No.5 shows that the correlation coefficients with both Pearson and Time Series methodsat k=0 are the same, confirming the calculated degrees of correlation. But beyond that, the results demonstrate that there may be a perfect correlation for the variables "type of cargo" and "port traffic" in the La Guajira PZ, a strong correlation for "coal" and "port traffic" in the Ciénaga PZ, as well as for "liquid bulk" and "port traffic" in the Golfo de Morrosquillo. Similarly, there is a correlation for "containerized cargo" and "port traffic" in the Cartagena PZ, while a weak correlation is observed for "liquid bulk" and "port traffic" in Santa Marta.

To confirm these results, the postulate of formula (4) will be taken into account.

$$r_{xy(k)} > \frac{1,96}{\sqrt{(N-k)}} \quad (4)$$

As can be seen in Table No.6, considering the previous postulate, it can be confirmed that there is a positive correlation between the analyzed variables. This constitutes statistically significant evidence of the relationship between the variables, and thus, the null hypothesis (H_{o0}) is accepted.

Port Zones	Type of load	Correlation Coefficient (Pearson)	Correlation Coefficient (time series)	Standard Error	$r_{xy(k)} > \frac{1,96}{\sqrt{(N-k)}}$
Cartagena	Contenedor	0,818	0,818	0,129	0,25284
Ciénaga	Carbón	0,995	0,995	0,129	0,25284
La Guajira	Carbón	1,000	1,000	0,129	0,25284
Golfo de Morrosquillo	Granel Liquido	0,991	0,991	0,129	0,25284
Santa Marta	Granel Liquido	0,404	0,404	0,129	0,25284

Table No. 6 Correlation Coefficient of the Atlantic Coast ZP by Type of Cargo 2018-2022
Source: The author with data from the statistical report of Supetranspote in Colombia 2018-2022

These results could be visually represented. For this purpose, the PZ of Cartagena was taken as an example. Graph No. 8 shows the correlation at k=0, as well as the correlations at lags k=0, k=1, k=2, k=-1, and k=-2.

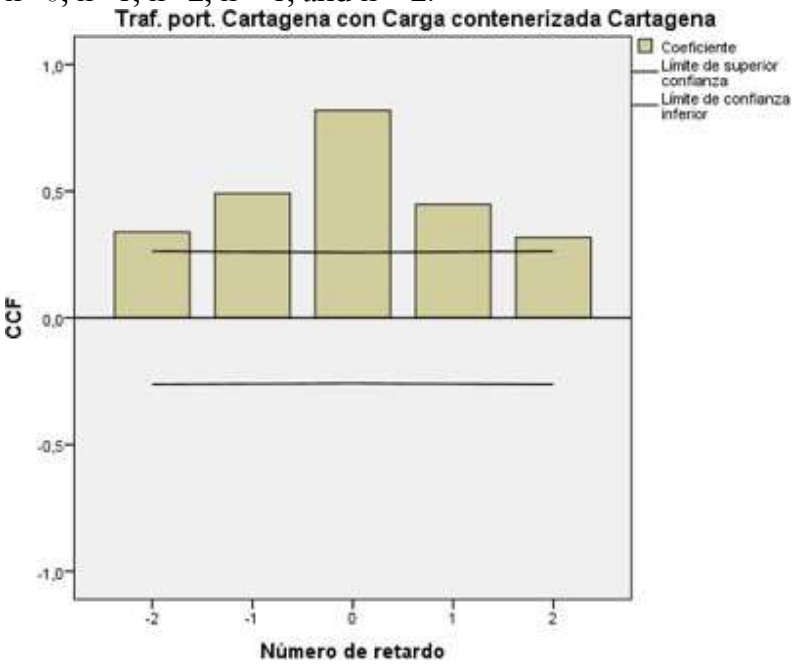

Figure 16: Correlogram Correlation PZ Cartagena Containerized Cargo 2018-2022.
Source: The author with data from the statistical report of Supetranspote in Colombia 2018-2022. In original Spanish language

Figure No. 17 clearly shows the behavior of the two signals or variables when overlaid by

subtracting the arithmetic means of each signal, which demonstrates a high correlation between the two.

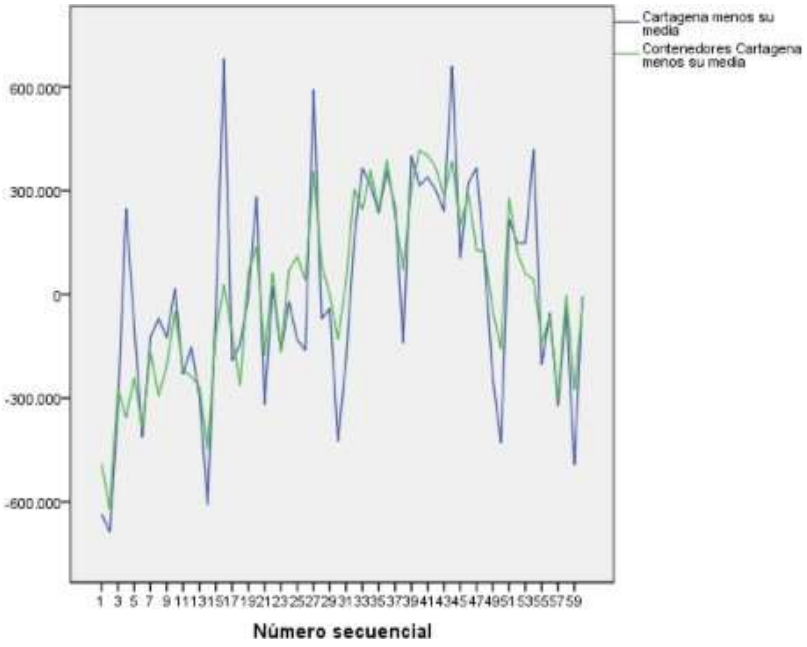

Figure 17: Sequence between the two variables PZ Cartagena Containerized Cargo 2018-2022. Source: The author with data from the statistical report of Supetranspote in Colombia 2018-2022. In original Spanish language

In order to analyze this further, the same process was carried out with the type of cargo related to port traffic in general in the Atlantic Coast PZs. This provides a clearer view of the influence of the type of cargo and how its variation affects port traffic in this region and the country.

Type of load	**Correlation Coefficient (Pearson)**	**Correlation Coefficient (time series)**	**Standard Error**	$r_{xy(k)} > \frac{1,96}{\sqrt{(N-k)}}$
Container	-0,219	-0,219	0,129	0,25284
Coal	0,793	0,793	0,129	0,25284
General	0,351	0,351	0,129	0,25284
Liquid Bulk	0,654	0,654	0,129	0,25284
Bulk Other Than Coal	0,020	0,020	0,129	0,25284

Table No. 7 Total Correlation Coefficient Atlantic Coast by Total Type of Cargo 2018-2022. Source: The author with data from the statistical report of Supetranspote in Colombia 2018-2022.

The results in Table No.7 show that the correlation coefficients in both methods are equal, and there is statistically significant evidence of the relationship between the types of cargo (coal, liquid bulk, and general) with the total port traffic in the PZs. Therefore, we accept the null hypothesis (H_0) that these types of cargo are determinants in the port traffic of the Atlantic Coast. The type of cargo with the best correlation is coal, as shown in Figure No.18.

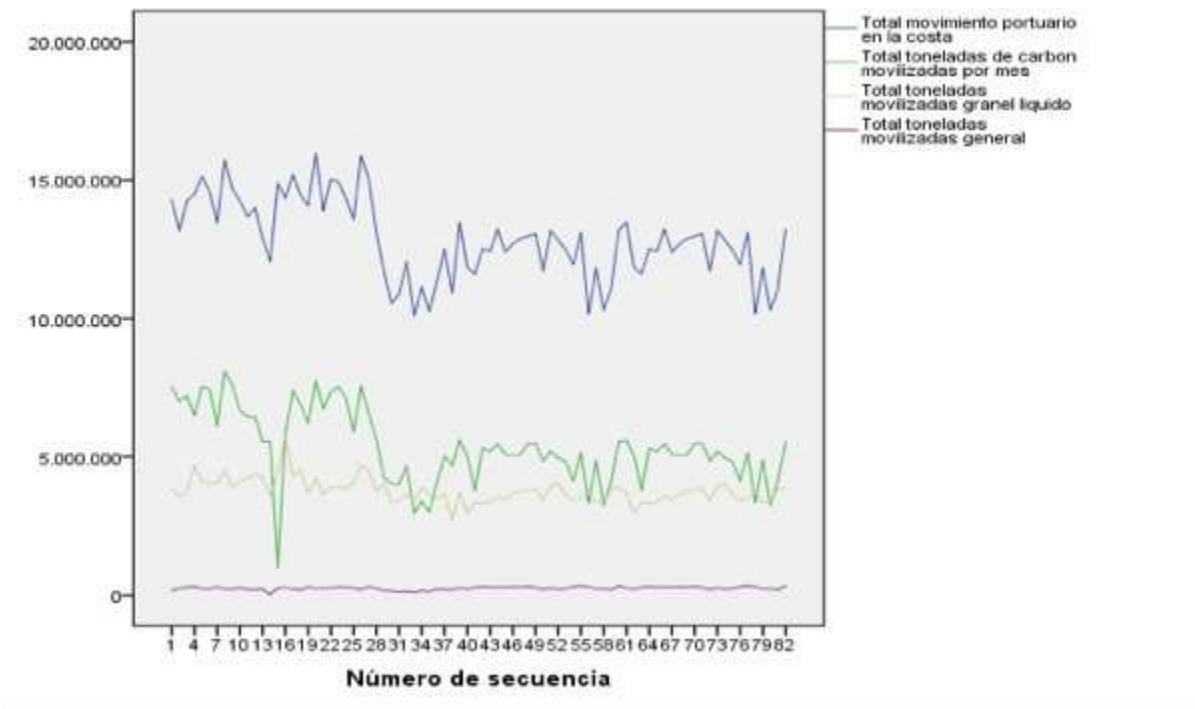

Figure 18: Sequence between Total Port Traffic Atlantic Coast and Types of Cargo: Coal, Liquid Bulk, and General 2018-2022.
Source: The author with data from the statistical report of Supetranspote in Colombia 2018-2022. In original Spanish language

Similarly, in seeking the relationship and influence on participation and port traffic, a correlation analysis was conducted between the variables of mobilized tons and the most significant port activity in each PZ according to its percentage participation. The PZs with the greatest impact or participation in Atlantic Coast port traffic were considered.

The results showed statistically significant evidence of the relationship between the predominant activities in each PZ and the total port traffic in the PZs, as shown in Table No.8. Therefore, the null hypothesis (H_o) is accepted.

These results corroborate that in Ciénaga, La Guajira, and Golfo de Morrosquillo, there are statistically significant differences in cargo traffic in the PZs of the Atlantic Coast, specifically in coal and liquid bulk exports. These activities and types of cargo may be affecting port traffic on the Atlantic Coast and in Colombia. This is evident because, during the analyzed period, these activities showed a negative variation, as illustrated earlier.

Port Zones	**Port Activity**	**Correlation Coefficient (Pearson)**	**Correlation Coefficient (time series)**	**Standard Error**	$\frac{1,96}{\sqrt{(N-k)}}$
Barranquilla	Importación	0,805	0,805	0,129	0,25284
Cartagena	Exportación	0,592	0,592	0,129	0,25284
	Importación	0,542	0,542	0,129	0,25284
	Trasbordo	0,704	0,704	0,129	0,25284
Cienaga	Exportación	1,000	1	0,129	0,25284

Golfo de Morrosquillo	Exportación	0,850	0,85	0,129	0,25284
La Guajira	Exportación	1,000	1	0,129	0,25284
Santa Marta	Importación	0,872	0,872	0,129	0,25284

Table No. 8 Correlation Coefficient Atlantic Coast PZ by Port Activity 2018-2022. Source: The author with data from the statistical report of Supetranspote in Colombia 2018-2022.

If we apply these procedures to the total port traffic on the Atlantic Coast, considering the most significant port activities in the PZs, it is evident that there is statistically significant evidence between exports and imports in the port traffic of the Atlantic Coast PZs, as shown in Table No.9. Therefore, it could be suspected that these two activities are influential and may be negatively affecting port traffic in this region and the country, as demonstrated earlier by their decrease during the analyzed period.

Port Activity	**Correlation Coefficient (Pearson)**	**Correlation Coefficient (time series)**	**Standard Error**	$\frac{1,96}{\sqrt{(N-k)}}$
Export	0,994	0,944	0,129	0,25284
Import	0,280	0,280	0,129	0,25284
Transshipment	-0,021	-0,021	0,129	0,25284
Coastal Shipping	-0,547	-0,547	0,129	0,25284

Table No. 9 Total Correlation Coefficient Atlantic Coast by Total Activity 2018-2022. Source: The author with data from the statistical report of Supetranspote in Colombia 2018-2022

CONCLUSION AND FUTURE WORK

This study focused on conducting a statistical analysis in the PZs of the Colombian Atlantic Coast to identify patterns in the instability of port traffic behavior in Colombia.

The results demonstrated a significant decrease in port traffic in these PZs during the analysis period. When comparing the cargo flows of the years 2018 and 2022, the average decrease in cargo movement was close to 16%. The PZs that experienced the most significant decrease during this period were La Guajira (40%), Ciénaga (33%), and Golfo de Morrosquillo (11%), representing 58.2% of the cargo moved on the Atlantic Coast.

Regarding the percentage variation in the participation of port traffic in the PZs of the Atlantic Coast, the most affected were Ciénaga and La Guajira, which showed average negative variations of -5.48 and -5.45, respectively, in the 2018-2022 period. This could be interpreted asa decrease in the production and export of coal from mines in La Guajira and Cesar. These ports are significant in the transport of coal, impacting the country's port traffic, as shown earlier.

Concerning the type of cargo transported through these PZs, it was found that Cartagena predominantly handles containerized cargo, while Ciénaga and La Guajira handle bulk coal. Golfo de Morrosquillo and Santa Marta handle liquid bulk, while Barranquilla and San Andrés do not have a predominant type of cargo. Ports like Ciénaga and La Guajira, where port activity other than coal is minimal, represent nearly 40% of cargo movement on the Colombian Atlantic Coast. Cartagena, on the other hand, represents 27% of this port traffic in the analyzed years. In the same way, Golfo de Morrosquillo stands out as the PZ with the

most liquid bulk movement in the region.

Concerning the port activities of these PZs, it was evident that Cartagena's strength lies in the export, import, and transshipment of cargo. However, in terms of exports, Ciénaga, Golfo de Morrosquillo, and La Guajira are the strongest. Barranquilla and Santa Marta excel in imports. To find reasons for the instability in port traffic and negative variation during the analyzed period, a correlation analysis (Pearson and time series) was conducted. It confirmed the hypothesis that the type of cargo and port activity are determinants in port traffic on the Atlantic Coast. This analysis showed that in Ciénaga, Puerto Bolívar, and Golfo de Morrosquillo, there are statistically significant differences in cargo traffic, particularly in the exports of coal and liquid bulk, indicating activities that may be affecting port traffic on the Atlantic Coast.

In future work, it is recommended to conduct a more in-depth statistical study to determine and identify competitiveness factors causing instability in port traffic in Colombia. Additionally, a competitiveness analysis should be performed to establish strategies that contribute to closingor opening gaps with other ports in the region.

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