Analysis of Port Infrastructure in Ports in the Colombian Caribbean and its Impact on Port Traffic in Colombia

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Abstract
Maritime trade throughout history has played an important role in the economic development of countries worldwide (Falla & Camargo, 2018), for which port infrastructure plays an important role in this. However, few studies have been dedicated to studying the influence it has on the movement of cargo in port terminals, so this research aims to analyze the port infrastructure of port terminals in the Colombian Caribbean and its impact on traffic. . Colombian port, using evaluation analysis and linear regression models, as tools to identify patterns that lead to its determination. The results showed that there is a compensation between the infrastructure variables analyzed, indicators that relate these variables and the tons moved between the port terminals analyzed. Likewise, there is statistically significant evidence of a relationship between these variables, which can account for the influence of one against the other.
Keywords: Port infrastructure, Port traffic, Columbian Caribbean Coast, Port evaluation.

1. INTRODUCTION

Port activity has managed to position itself as the most important when it comes to international trade, since, through ports, most of it is currently mobilized, as authors point out that "currently 80% of international trade moves through seas and oceans" (Castillo and Trujillo 2021). This situation has forced ports to strengthen their infrastructure, in order to become competitive in this sector of the economy and counteract the formation of queues in them.
Therefore, port infrastructure, defined by Clavero (2017) as "the set of civil works and mechanical, electrical and electronic installations, fixed and floating, built or located in ports, to facilitate transport and modal exchange", has taken on great importance in this area of the world economy, becoming one of the most relevant factors in the industry. For this reason, port administrators, port authorities, investors, users and researchers have focused their interest in it, whether for investment, modernization, optimization, research, investment or use of the services.

The constant growth of port dynamics worldwide is forcing this sector of the economy to focus its gaze on this factor, for competitiveness purposes, with the purpose of strengthening the capacity of services offered to international trade, although the sector has been affected by the war conflict with Ukraine. the United Nations Conference on Trade and Development (UNCTAD), projected that the growth of world maritime trade would moderate to 1.4% this year (2022) and remain at that level in 2023, according to news from the port sector on the page of the port society of the Port of Santa Marta on November 29, 2022.

On the other hand, port traffic in the Andean community, according to member country, for the year 2021, cargo traffic through its ports amounted to 324,951 thousand tons, a figure that represented an increase of 9.9%, compared to the previous year, Andean Community (2021). However, in Colombia this dynamic measured in the tons mobilized in the years 2021 and 2022, according to statistical data from the Superintendence of Transport (Supertransporte), has decreased by about 0.5% and about 15% in the period from 2018 to 2022, Vargas and Estrada (2023); so the objective of this research, It focuses on analyzing the port infrastructure of the ports of the Colombian Caribbean and its impact on Colombian port traffic.

This research will be structured as follows: methodology, literature analysis, results and discussion, conclusions and future works, and finally, the bibliographic references that support it.

METHODOLOGY

By its nature, this research is framed in a descriptive methodology, which Hernández (1991, p. 60) defines "Descriptive Studies seek to specify the important properties of people, groups, communities or any other phenomenon that is subjected to analysis". In this research, the population will be composed of all the Port Companies of the Colombian Caribbean coast, from which the SPs that present the highest cargo movement in each Port Zone of this region of the country in the period between 2018 and 2023 will be extracted.

After having determined the SPs that will be part of ours, the port infrastructure will be analyzed in them, through a bibliographic review of literature, port portals and institutions, such as the Supertransporte, applying statistical methods to them in order to find patterns that characterize it.

For the above, port variables such as: No. of docks, Dock length, Dock draft or depth, No. of cranes, Yard area and Warehouse area will be used; and indicators such as: Tons per linear meter of dock, Yard Utilization, Warehouse Utilization and Operational Efficiency.

In the search for influence between the port infrastructure and the port traffic of these SPs, correlation models and multiple line regression will be used, which will allow finding correlations between the variables and statistically significant evidence of the influence of one on the other.

LITERATURE REVIEW

Port infrastructure is being studied by many authors for various purposes, as Sun and Kauzen (2023) studied the essential role in the development and economy and transport

of goods and services in Tanzania, based on the question of the level of impact of a port infrastructure on the economy of that East African country. In order to answer the question, the authors evaluated the impact of port infrastructure and its influence on the economic growth of this low-income country, for which they used the structural equation model (SEM) and with statistical data, they analyzed the relationship of variables and determined the influence on economic growth. The results showed that there is a direct relationship between Tanzania's port infrastructure, economy and international trade; likewise, a significant relationship between economic growth and international trade was demonstrated.

In the same way, Sekar (2023) studied how port infrastructure affects India's gross domestic product and economic development, for which he studied the twelve most important ports in the country, setting himself the goal of "discovering how port infrastructure influences performance and operating income and also discovering how ports contribute to the economic development of the country". using Pearson's correlation coefficient, in order to determine the relationship between variables such as: the number of moorings, performance and operating income. The results showed that port infrastructure contributes significantly to the country's GDP and contributes considerably to the generation of employment in the country.

For their part, Goldar & Paul (2018) studied the "impact of port infrastructure development and efficiency in port operations on export performance", the authors econometrically analysed port data of India's exports from six main categories of manufactured goods, for the period 2001-2002 to 2014-2015. The data used for the analysis corresponded to 11 important ports in that country, in which four port efficiency indicators were taken into account: the berth occupancy rate, the percentage of idle berths, the response time and the waiting time before berthing. The econometric analysis showed that efficiency in port operations has a positive effect on exports; likewise, the expansion of port capacity contributes to the growth of exports; However, the impact of port capacity expansion on export growth is relatively small for a port where the current level of facility utilization is low.

Similarly, Ahmed et al (2023) examined the relationship between logistics performance indices and the quality of port infrastructure in Tunisia and Morocco, with the aim of "developing a model to assess the quality of port infrastructure. In order to evaluate the development of port infrastructures to improve the competitiveness of port systems in two North African countries according to nine competitiveness factors", in this one they used the regression model and partial least squares, in order to establish relationships between the selected competitiveness factors. This demonstrated that there is a significant influence between the competitiveness factors identified in relation to the quality of port infrastructure; They also found that it is of utmost importance to improve logistics performance, which would contribute to the improvement of port infrastructure and maritime trade, and, consequently, economic growth. In the same way, they identified that Morocco has the best port infrastructure, which can lead it to improve its competitiveness.

Gómez & Ortega (2019) on the other hand, studied how emerging capacities can impact the positioning of ports handling containerized cargo, so they set out to establish "the positioning of the infrastructure and equipment capacities of ports in the face of an environment of port growth in Central America and the Caribbean", the authors carried out a bibliographic review, and identified various factors influencing competitiveness; In

the analysis of the review, they established that the "technological balance" denoted by the number of port cranes and docks assigned to containerized cargo, is the engine that drives the performance of these terminals. Likewise, the results demonstrated a greater correlation between the movement of containerized cargo in terminals that have the largest number of cranes, which means greater operational efficiency in terms of time and costs.

As can be seen, port infrastructure has been taken into account to address different port problems. However, few have studied the influence of this on port traffic, which we will deal with in this research.

RESULTS AND DISCUSSION

In Colombia, the port structure is divided into Port Zones (ZP), and this, in turn, into Port Societies (SP), the former being a total of twelve, "according to the Superintendence of Transport of Colombia "Supertransporte", of which eight of them are located on the Atlantic coast: La Guajira, Santa Marta, Ciénaga, Barranquilla, Cartagena, Gulf of Morrosquillo, ZP. Magdalena and San Andrés River; three on the coast on the Pacific Ocean: Buenaventura, Turbo and Tumaco and the ZP of Barrancabermeja on the banks of the Magdalena River at the height of the municipality of the same name". Vargas & Estrada (2024). Likewise, it is highlighted that 84.56% of port traffic occurs through the ZPs of the Colombian Atlantic coast, according to statistical data from the same source, which is why this research will focus on the most important SPs (according to their volume of cargo transported in tons) in this region of the country.

In this order of ideas, the following table shows the most important SP in terms of Ton. mobilized in each SPA of the Atlantic coast, in the period from January 2018 to June 2023, and will be the object of study of this research.

Port Zone	Port Society	Ton. Mobilized
Cartagena	Ecopetrol S. A	35.238.081
	Port of Mamonal S. To	9.820.237
	Port Society of Puerto Bahia	16.701.141
	Sociedad portuaria Regional Cartagena S. To	34.599.444
	Cartagena Container Terminal S. To	106.160.525
Swamp	American Port Company Inc.	164.787.186
	Sociedad Portuaria Puerto Nuevo S. To	43.850.977
Barranquilla	Associated Port Company	6.790.670
	Palermo Sociedad Portuaria S. To	13.512.296
	Sociedad Portuaria Regional Barranquilla S. To	24.056.010
Gulf of Morrosquillo	Cenit Transporte y Logística de Hidrocarburos S. To	60.749.620
	Compañía de Puertos Asociados S. To	6.062.143
	Oleoducto Central S. To	91.326.954
Guajira	Cerrejón Zona Norte S. To	111.317.681
	Puerto Brisa S. A	6.171.167

San Andrés	San Andrés Port Society S. To	1.410.621
Santa Marta	Cenit Transporte y Logística de Hidrocarburos S. To	28.515.022
	Sociedad Portuaria de Santa Marta S.A	31.050.371
Magdalena River	Puerto Pimsa S.A	695.530

Table No.1 Port Companies with the highest activity according to their ZP on the Colombian Atlantic Coast January 2018- June 2023.
Source: The author with data from the statistical report of the Supetranspote in Colombia 2018-2023

Analysis of port infrastructure

When analyzing the port infrastructure in the nineteen (19) selected SPs, taking into account variables such as: number of docks, dock length, dock draft or depth, warehouse area, yard area, number of cranes; likewise, efficiency indicators such as: tons per linear meter of dock, use of warehouses, use of yards and operational efficiency, it was found that, for example, the SPs with the longest docks in linear meters in their order from highest to lowest (as shown in Table 2) are, SP of Santa Marta S.A with 2061, Oleoducto Central S.A 1440, Terminal de Contenedores de Cartagena 1000, SP Puerto Bahía 925, SP Regional Cartagena 877; an important variable to take into account, because it will allow calculating indicators such as the tons per linear meter mobilized in port. Likewise, the length of the dock in a port is important, since it facilitates the maneuvers of ships, as well as it can determine the type and number of ships that can dock in it, likewise, it can determine the ability to adapt to different types of ship, or the capacity to handle the transported merchandise and safety of operations.

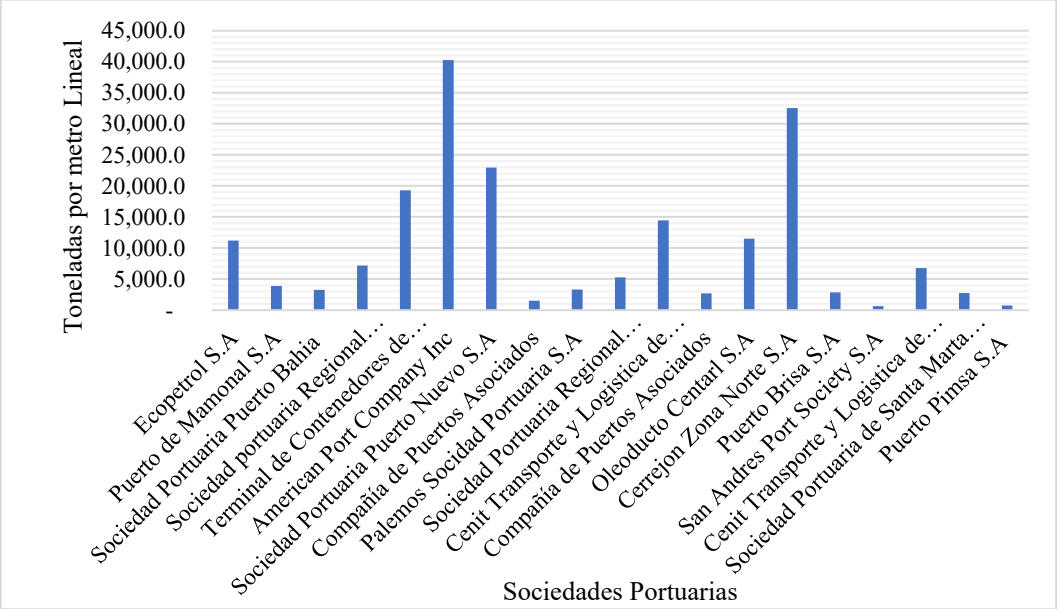
Port Zone	**Port Society**	**Spring length in linear Mt.**
Cartagena	Ecopetrol S. A	571
	Port of Mamonal S. To	460
	Port Society of Puerto Bahia	925
	Sociedad Portuaria Regional Cartagena S. To	877
	Cartagena Container Terminal S. To	1000
Swamp	American Port Company Inc.	744
	Sociedad Portuaria Puerto Nuevo S. To	347
Barranquilla	Associated Port Company	1400
	Palemos Sociedad Portuaria S. To	738
	Sociedad Portuaria Regional Barranquilla S. To	830
Gulf of Morrosquillo	Cenit Hydrocarbon Transport and Logistics	763
	Associated Port Company	1400
	Oleoducto Central S. To	1440
Guajira	Cerrejón Zona Norte S. To	622
	Puerto Brisa S. A	360
San Andrés	San Andrés Port Society S. To	415

Santa Marta	Cenit Hydrocarbon Transport and Logistics	763
	Sociedad Portuaria de Santa Marta S: A	2061
Magdalena River	Puerto Pimsa S.A	175

Table No.2 Dock Length SP Colombian Atlantic Coast
Source: The author with data from SP portals

The dock length data, compared with the indicator "Tons per linear meter mobilized in port", using formula 1, used in the "Port efficiency and waste disposal indicators First Semester 2023" of the Supertransporte, but using the average of tons mobilized in the period of analysis of this research, reveals that, the SPs with the best index, are in their order as shown in Graph 1: American Port Company Inc. 40,270.6 Ton/Mt. Lineal, followed by Cerrejón Zona Norte S.A mobilizing 32,539.5 Ton/Mt. Lineal, Sociedad Portuaria Puerto Nuevo S.A with 22,976.7 Ton/Mt. Lineal, Terminal de Contenedores de Cartagena S.A 19,301.9 Ton/Mt. Lineal, Cenit Transporte y Logística de Hidrocarburos (Golfo de Morrosquillo) with 14,476.3 Ton/Mt. Lineal.

$$\text{Toneladas por Mt. Lineal de muelle} = \frac{promedio\ total\ Ton.\ movilizadas}{Total\ Mts.\ lineales\ de\ muelle} \quad (1)$$



Graph No.1. Tons per linear meter of dock mobilized in port
Source: The author with data from the statistical report of the Supetranspote in Colombia 2018-2023. In original Spanish language

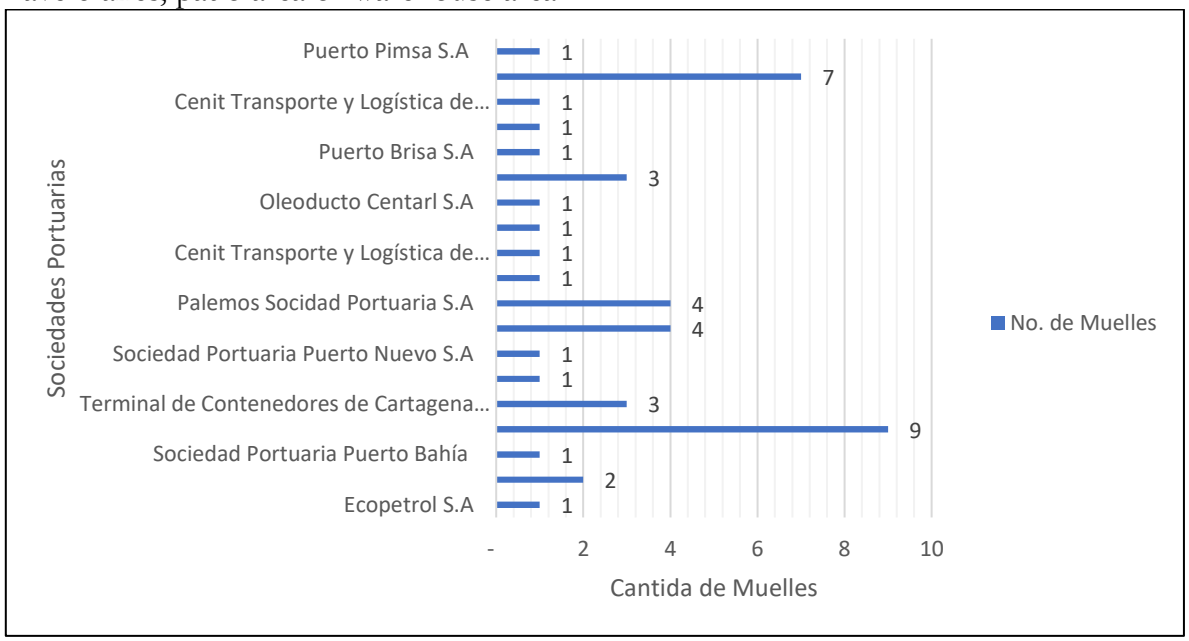
Taking into account that, according to Boske (2003), cited Gómez-Rudy & Ortega (2019) "the installed capacity of ports, in terms of equipment and space capacity, boosts their level of competitiveness to the extent that they have appropriate, modern and sufficient infrastructures based on market demand", it was built through a bibliographic review highlighted by the SP portals, and information provided by the Supertransporte in Table 3, which contains relevant aspects in relation to the infrastructure variables of the SPs under study.

Port Zone	Port Society	No. of Springs	Length of Pier in Mts.	Draft or Depth of Dock in Mts.	No. of Cranes	Patio area m2	Warehouse Area m2
Cartagena	Ecopetrol S. A	1	571	13	0	0	0
	Port of Mamonal S. To	2	460	14,5	10	237.480	2.520
	Port Society of Puerto Bahia	1	925	17	4	157.381	3.712
	Sociedad Portuaria Regional Cartagena S. To	9	877	15,5	40	242.094	9.076
	Cartagena Container Terminal S. To	3	1000	17	73	62.303	28.265
Swamp	American Port Company Inc.	1	744	20,5	0	107.642	0
	Sociedad Portuaria Puerto Nuevo S. To	1	347	18,4	0	250.000	0
Barranquilla	Associated Port Company	4	1400	10	1	145.420	4.350
	Palemos Sociedad Portuaria S. To	4	738	13	4	91.984	7.126
	Sociedad Portuaria Regional Barranquilla S. To	1	830	8,8	18	183.794	49.667
Gulf of Morrosquillo	Cenit Hydrocarbon Transport and Logistics	1	763	25	0	0	0
	Associated Port Company	1	1400	12,5	1	40.402	6.509
	Oleoducto Central S. To	1	1440	29	0	0	0
Guajira	Cerrejón Zona Norte S. To	3	622	19,5	0	630.000	0
	Puerto Brisa S. A	1	360	17,5	0	480.000	10.000
San Andrés	San Andrés Port Society S. To	1	415	7,7	11	23.181	1.600
Santa Marta	Cenit Hydrocarbon Transport and Logistics	1	763	30	0	0	0

	Sociedad Portuaria de Santa Marta S. To	7	2061	17,37	8	110.020	7.512
Magdalena River	Puerto Pimsa S.A	1	175	8,6	2	0	0

Table No.2 Dock Length SP Colombian Atlantic Coast
Source: The author with data from SP portals

The above shows that, for example, in relation to the number of docks, the Sociedad Portuaria Regional Cartagena S. A with 9 docks, Sociedad Portuaria de Santa Marta S. A, Compañía de Puertos Asociados y Palemos Sociedad Portuaria S. A with 4, Terminal de Contenedores de Cartagena S.A with 3 as well as Cerrejón Zona Norte S. A and Puerto de Mamonal S. A with 2 as can be seen in graph 2. Likewise, when referring to the draft or depth of the dock, the SP American Port Company Inc. stands out with a depth of 20.5 meters, Cerrejón Zona Norte S.A with 19.5, Sociedad Portuaria Puerto Nuevo S.A with 18.4 and with 17 or more Puerto Brisa S.A, Sociedad Portuaria de Santa Marta S.A, Terminal de Contenedores de Cartagena S.A and Sociedad Portuaria Puerto Bahía. In the analysis of this variable, it is necessary to note that ports such as Cenit Transporte y Logística de Hidrocarburos (Santa Marta), Oleoducto Central S.A. and Cenit Transporte y Logística de Hidrocarburos (Golfo de Morrosquillo), are exclusively oil ports and due to their port activity, they have a Monobuoy, which is a "cylindrical body or floating square type divided into two parts, one that we can call fixed to which the anchoring systems are incorporated to the bottom, and the other rotating on the previous one, which is the one that supports the mooring installations to the boat" (Reyes 2021). which acts as a dock, so its depth is greater than the docks of other SPs; likewise, they do not have cranes, patio area or warehouse area.



Graph No.2. Number of docks by Port Society
Source: The author with data from the statistical report of the Supetranspote and port portals. In original Spanish language

Regarding the crane capacity of the SPs, it can be observed that due to its port activity, Terminal de Contenedores de Cartagena S.A. stands out, which contains a total of 73 cranes in its infrastructure; likewise, Sociedad Portuaria Regional Cartagena S.A has 40, followed by Sociedad Portuaria Regional Barranquilla S.A, 11 San Andrés Port Society S.A, Puerto de Mamonal S.A with 10 and Sociedad Portuaria de Santa Marta S.A with 8, pointing out that these operate as multipurpose port terminals.

The same table shows that in terms of the yard area available to the SPs for their operations, Cerrejón Zona Norte S.A and Puerto Brisa S.A are the ones with the largest area with 630,000 and 480,000 square meters respectively, followed by Puerto Nuevo S.A with 250,000, Sociedad Portuaria Regional Cartagena S.A with 242,094, Puerto de Mamonal S.A with 237480. It should be noted that the first three SPs base their activity on the export of coal.

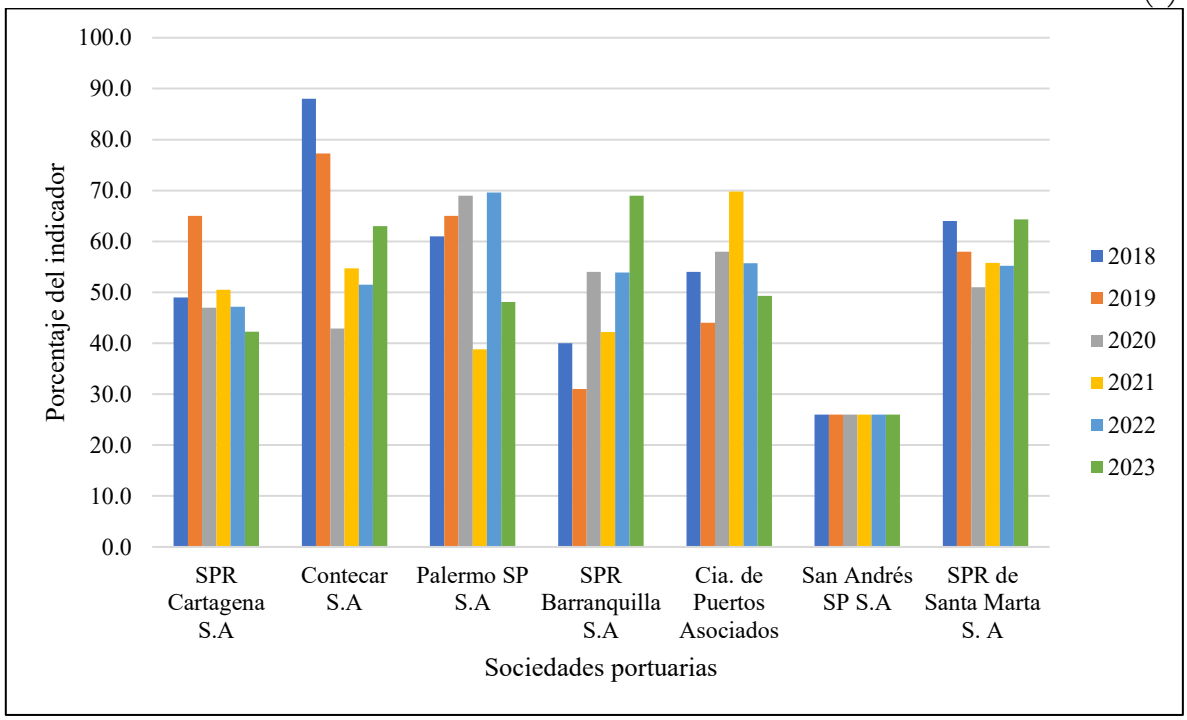
When analyzing the installed capacity of the SPs, in relation to the warehouse area in square meters they have, it can be seen that the Sociedad Portuaria Regional Barranquilla S.A leads this variable, with a total area of 49,667 square meters, followed by Terminal de Contenedores de Cartagena S.A, with 28,265 and Puerto Brisa S.A with 10,000. it is highlighted here that the SPs that lead this item are multipurpose port terminals; however, Puerto Brisa, despite having been created as a multipurpose port, bases its port activity on 90% of the transport of coal, which would mean an underutilization of its warehouse area, a situation that we will be able to corroborate later. Likewise, it is noted that ports such as Ecopetrol S.A, Cenit Transporte y Logística de Hidrocarburos (Golfo de Morrosquillo), Oleoducto Central S.A, Cenit Transporte y Logística de Hidrocarburos (Santa Marta), do not have an area of yards or warehouses, because their port activity is the transport of hydrocarbons, that is, they are oil ports. For its part, due to the characteristics of Puerto Pimsa, it does not have these analysis variables either; in this, "storage takes place in the Malambo industrial park, adjacent to the concession area, where at the request of the client it is possible to store the cargo both in own and rented warehouses. The industrial park has 40 hectares available for storage" (taken from the Puerto Pimsa portal).

On the other hand, when reviewing the efficiency indicators, which "allow the organization or the process to optimize the resources assigned for the achievement of the goals, that is, to know how to manage what the entity has (resources) to obtain the appropriate result, how was it done?, this type of indicators allows us to know the progress of the goal against the resources used for its development" (Minacienda 2019). that in this research, it will analyze efficiency indicators tons per linear meter of dock, use of warehouses, use of yards and operational efficiency.

In these, it was found that, for example, for the indicator Exploitation of warehouses, according to statistical data from the Supertransporte, Taking into account that this indicator aims to set the level of use of warehouses by the SPs in a given period and corresponds to the capacity that they have to offer, calculated by formula (2), it is highlighted that the Cartagena Container Terminal S.A (Contecar S.A) has presented the best performance in the period analyzed, despite having fallen 20 percentage points for the year 2020, according to its average (62.9%), Palermo SP S.A and SP Regional Santa Marta S.A. are also highlighted in this indicator. which have presented an important indicator (on average 58.6% and 58.1% respectively); however, in Palermo, there is a drop of 20 percentage points according to its average for the year 2021, and 10 points for 2023, which shows some instability or variability, while Santa Marta shows some stability

in the indicator, It should also be noted that the SP with the lowest use of wineries, it is SP San Andrés S.A., with a constant percentage of 26%, which may indicate an underutilization of its warehouse capacity, as can be seen in Graph No.3 and Table.3.

$$Aprobechamiento\ de\ bodegas = \frac{Capacidad\ utilizada\ de\ bodegas}{Capacidad\ disponible\ de\ bodegas} * 100 \quad (2)$$



Graph No.3. Warehouse Utilization

Source: The author with data from the statistical report of the Supetranspote and port portals. In original Spanish language

Port Society	Year						
	2018	2019	2020	2021	2022	2023	Prom
SPR Cartagena S. A	49,0	65,0	47,0	50,5	47,2	42,3	50,2
Contecar S. To	88,0	77,3	42,9	54,7	51,5	63,0	62,9
Palermo SP S. A	61,0	65,0	69,0	38,8	69,6	48,1	58,6
SPR Barranquilla S. A	40,0	31,0	54,0	42,2	53,9	69,0	48,4
Associated Ports Company	54,0	44,0	58,0	69,8	55,7	49,3	55,1
San Andrés SP S. A	26,0	26,0	26,0	26,0	26,0	26,0	26,0
SPR of Santa Marta S. To	64,0	58,0	51,0	55,8	55,2	64,3	58,1

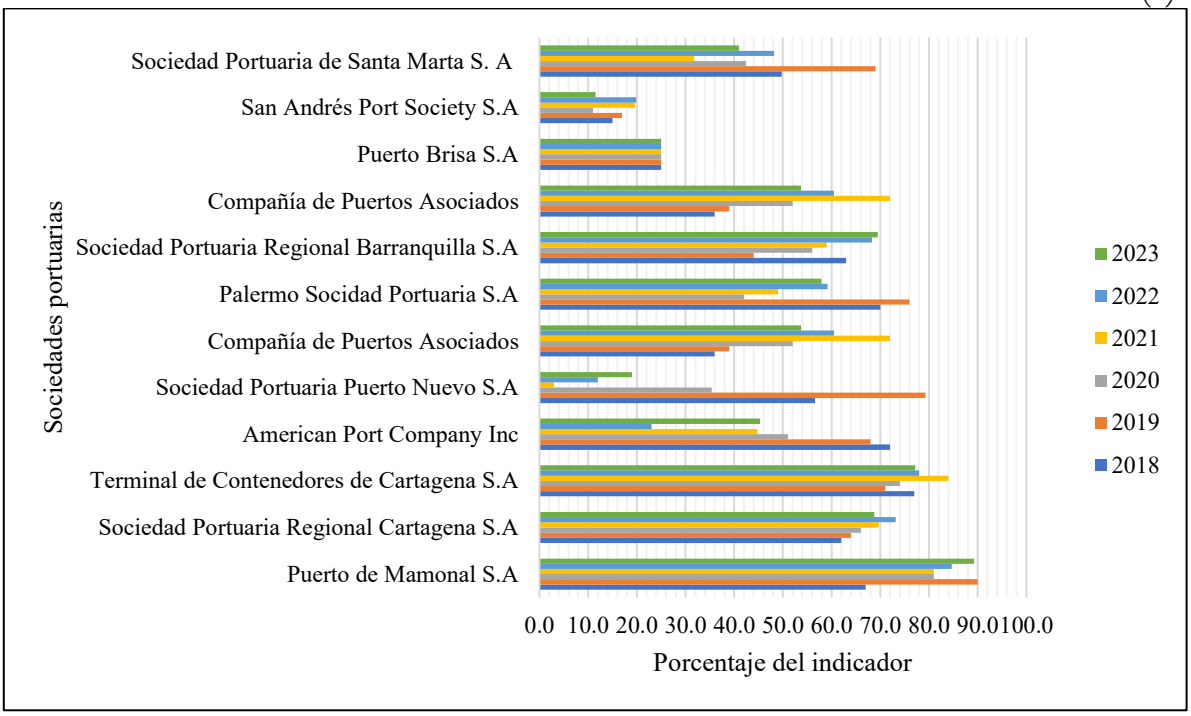
Table No.3 Use of warehouses

Source: The author with data from the statistical report of the Supetranspote and port portals

Likewise, when analyzing the Playground Utilization indicator, which seeks to know the level of utilization of the playground area that the SPs have in a given period, thus determining the supply capacity of this variable per period analyzed, which will be calculated with formula (3). The results indicate that the Port of Mamonal S.A. presents an interesting use of yards, with an average of 82.2% and with an acceptable variation in the period analyzed, which can be interpreted as a good offer and reception of yard services, likewise, the Cartagena Container Terminal (Contecar) and SPR of Cartagena stand out in this indicator with an average of 76.9% and 67.3% respectively, and with

low variation in the period (it is highlighted that these port companies with the highest indicator belong to the ZPs of Cartagena). On the contrary, the port companies San Andrés and Puerto Brisa have very low percentages of yard use according to their availability, of 15.7% and 25% respectively, reflecting a negative evaluation of their capacity to offer the service.

$$Aprobechamiento\ de\ patios = \frac{Capacidad\ utilizada\ de\ patios}{Capacidad\ disponible\ de\ patios} * 100 \quad (3)$$

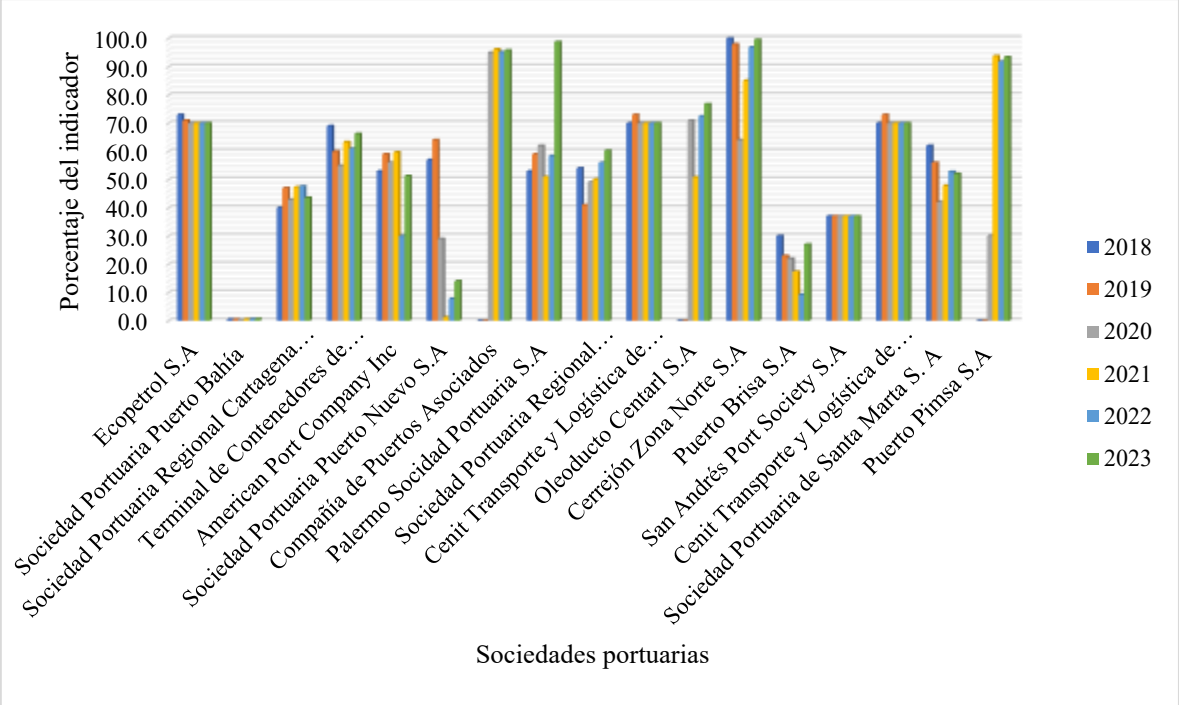


Graph No.4. Use of courtyards
Source: The author with data from the statistical report of the Supetranspote and port portals. In original Spanish language

In relation to the Operational Efficiency indicator, which seeks to measure the effective utilization of capacity in terms of infrastructure of the SPs, which allows estimating the level of utilization of port facilities, calculated using formula (4); it was found that the ports with the best indicator were the associated port company and Cerrejón northern zone, with a percentage of efficiency in the effective utilization of their infrastructure capacity of 95.6% and 90.6% respectively, it is also highlighted that the SPs with the lowest indicator were Puerto Bahía, Puerto Brisa and Puerto Nuevo with average percentages in the analyzed period of 0.5%. 21.5% and 28.8%, well below the average of the SPs that were the object of this research, which was 56.3%, which could represent an underutilization of their port infrastructure.

Operational efficiency = (Used capacity / Available capacity) × 100

(4)



Graph No.5. Operational efficiency

Source: The author with data from the statistical report of the Supetranspote and port portals. In original Spanish language

In order to establish the incidence of the structure and efficiency indicators analyzed in port traffic in the SPs under study, the correlations between these variables and the movement of cargo in the analyzed ports were calculated, seeking to know if there is a statistically significant relationship between them. For this, the Pearson relationship coefficient will be used, taking into account that it is important to distinguish that what the Pearson coefficient measures is the strength and direction of the linear relationship between the variables (Hernández, et al. 2018), which could be an indicator of influence and not of causality of one variable over the other. For this, we will use equation (5). Where the variable "x" represents the tons mobilized in each SP analyzed, and the variable "y" No. of Docks, Dock Length in Mts., Draft or Depth of Dock in Mts., No. of Cranes, Yard Area m2 and/or Warehouse Area m2, likewise "$\bar{x}$" and "$\bar{y}$" represent the averages in each of them respectively.

$$r_{xy} = \frac{\sum[(x_i - \bar{x}) * (y_i - \bar{y})]}{\sqrt{\sum(x_i - \bar{x})^2 * \sum(y_i - \bar{y})^2}} \quad (5)$$

When performing the calculations with each pair of variables, i.e. the variable "x" Ton. Mobilized, with each of the variables "y", it was found that the variables analyzed are related to the movement of cargo in the SP analyzed mostly, except with the variables No. of docks, area of warehouses and use of yards, with which the correlation is almost zero, likewise, a weak correlation between variable "x" and Length of dock, No. of cranes, Yard area, Warehouse use and Operational efficiency, in addition, a moderate and positive correlation with the variable Draft or depth of the dock, which could indicate that the greater the depth of the dock greater the movement of cargo in the SP, likewise, it can be noted that there is a strong positive linear correlation between the variables Ton. Mobilized and Tons per linear meter of dock, since its correlation coefficient is 0.916,

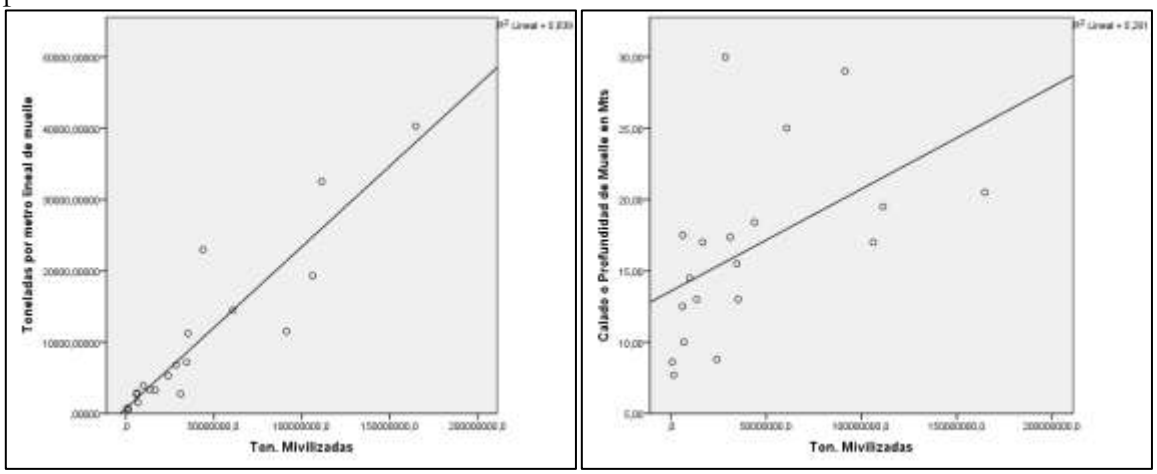
which would mean that the more tons per linear meter of dock, the greater the port traffic in the SPs analyzed.

On the other hand, the results show that there is a statistical significance between the Ton variable. Mobilized, with the variables Pier Draft and Ton. Per linear meter, since the level of significance is 0.025 and 0.000 respectively, both less than 0.05, which could mean that these variables are related; however, they do not imply causation. In order to confirm these results, scatter plots with trend lines were constructed, which, for these two variables, demonstrated the positive correlation and statistical significance between these pairs of variables, as shown in Graph 6.

Related sample correlations			
Correlation by pairs of variables	N	Correlation	Say.
Ton. Mobilized and No. of Docks	19	-,040	,872
Ton. Mobilized and Length of Dock in Mts	19	,255	,293
Ton. Mobilized and Draft or Depth of Dock in Mts	19	,511	,025
Ton. Mobilized and No. of Cranes	19	,193	,429
Ton. Mobilized and Courtyard Area m2	19	,121	,621
Ton. Mobilized and Warehouse Area m2	19	-,038	,879
Ton. Mobilized and Tons per linear meter of dock	19	,916	,000
Ton. Mobilized and Warehouse Utilization	19	-,196	,420
Ton. Mobilized and Yard Use	19	-,011	,964
Ton. Mobilized and Operational Efficiency	19	,185	,449

Table 4. Related sample correlations

Source: The author with data from the statistical report of the Supetranspote and port portals



Graph No.6. Scatter Plots

Source: The author with data from the statistical report of the Supetranspote and port portals. In original Spanish language

While the above demonstrates a correlation between the variables, Ton. Mobilized and Ton. Per linear meter of dock, and also Ton. Mobilized and Dock Draft, this is not enough to demonstrate influence between them, so, to try to explain this, and find some sign of causality between the variables, the linear regression model was used, which,

according to Montero (2016) tries to fit linear or linearized models between a dependent variable and more than one independent variable. for his part, Hernández et. Al (2019) mentions that correlation is limited to measuring the strength of association between two characteristics by treating them symmetrically, regression proposes a linear model in which the changes observed in one variable would be explained due to the effect of others. Therefore, this statistical tool overcomes the constraints of the correlation coefficient by asymmetrically posing the link between variables, considering one as dependent and others as independent. For all of the above, linear regression analysis can shed some light on causality between the Ton variable. Mobilized as a dependent variable and the independent variables taken into account in this study.

To achieve this, equation (6) was used in which:

yj is the dependent variable.

xkj is the dependent variable.

bj This is the beta coefficient of the model.

uj They represent the residuals of the model.

$$y_j = b_0 + b_1 x_{1j} + b_2 x_{2j} + b_k x_{kj} + u_j \quad (6)$$

With the help of the SPSS in the calculations, the results could be obtained; initially, an ANOVA test was performed, which could give a little more clarity in this regard, since the ANOVA "is applied in order to analyze the significant differences or similarities of both the means and the variances, where a high or low ratio would imply the acceptance or rejection of the hypothesis, and on the other hand, the effect that one variable has on the other according to its population in terms of its degree of predictability will be revealed, to a greater or lesser covariance" (Robles 2013), likewise, it shows the goodness of the model. In this case, as shown in Table 5, where it is initially seen that the model has a significance less than 0.05; therefore, it is statistically significant to explain the dependent variable.

However, if it is considered that the tons mobilized by the port terminals under study are not influenced by the independent variables (H0) and the results of the Anova of the model are analyzed, it would have to be considered to reject that statement (H0) and accept that, if there is an influence between the variables, since the significance value is less than 0.05; therefore, there is statistical evidence that at least one independent variable affects or influences the dependent variable.

ANOVAb					
Model	Sum of squares	Good luck	Mean square	F	Sig.
Regression	3,562E16	10	3,562E15	18,495	,000a
Residual	1,541E15	8	1,926E14		
Total	3,716E16	18			

Table 5. Model Anova

to. Predictor variables: (Constant), Operational efficiency, Dock Draft or Depth in Mts, No. of Docks, Yard Area m2, Warehouse Area m2, Tons per linear meter of dock, Yard Utilization, No. of Cranes, Dock Length in Mts, Warehouse Utilization

b. Dependent variable: Ton. Mobilized

Source: The Author

Likewise, the model explains 90.7% of the variance of the dependent variable, which means that a high percentage of the independent variables explain the Ton variable. Mobilized in the study ports, as shown by the R-square in Table 6.

Model Overviewb									
				Typo error. of the estimate	Change statistics				
Model	R	R squared	Corrected R-squared		Change in R squared	F change	GL1	GL2	Sig. F change
1	.979a	,959	,907	13878550,6477	,959	18,495	10	8	,000

Table 6. Model Overview

to. Predictor variables: (Constant), Operational efficiency, Dock Draft or Depth in Mts, No. of Docks, Yard Area m2, Warehouse Area m2, Tons per linear meter of dock, Yard Utilization, No. of Cranes, Dock Length in Mts, Warehouse Utilization

b. Dependent variable: Ton. Mobilized

Source: The Author

Now, regarding the influence of the independent variables, it can be noted that according to the significance in the t-test, the variables dock length and tons per linear meter of dock, if it explains the Tons. Mobilized, since their significance is less than 0.05, while the rest of the variables are not related to the Tons. Mobilized, since their level of significance is greater than 0.05; on the other hand, the beta coefficient (ß) in the model shows that the independent variable that most explains the Tons. Mobilized is Ton. Per linear meter of dock with 0.805, followed by Dock Length and No. of cranes with 0.375 and 0.248 respectively, a situation that coincides with the Pearson correlation model used.

a. Dependent variable: Ton. Mobilized

b. Source: The Author

All of the above suggests an influence or relationship (defined by the equation **Ton. Mobilized**) of the independent variables used, on the dependent Ton. Mobilized, some to a large extent, such as Ton. Per linear meter of dock, length of dock, even No. of cranes; others such as, Operational efficiency, yard utilization, warehouse utilization and No. of docks, to a lesser extent, and others, with a much smaller influence such as Warehouse Area, Yard Area and Dock Draft, as shown by the partial correlation in the model.

Ton. Mobilized = - 31108664,512 - 3183664,053(No. of Docks) + 39999,563(Dock Length in Mts) -64115,311(Dock Draft or Depth in Mts) + 616272,046(No. of Cranes) -4,125(Yard Area m2) -196,709(Warehouse Area m2) + 3254,874(Tons per linear meter of dock) -377630,057(Warehouse Utilization) + 20160,510(Yard Utilization) + 287487,742(Operational Efficiency).

CONCLUSION AND FUTURE WORK

The purpose of this research was to analyze the port infrastructure of the ports of the Colombian Caribbean and its impact on Colombian port traffic, so that, according to the results of the analysis of the 19 SPs due to their importance in cargo movement in this part of the country, it can be said that:

SPs such as SP Regional Cartagena, SP Regional Santa Marta have a strength in the number of docks they have for their port traffic; while others such as Oleoducto Central, SP regional Santa Marta, Compañía de Puertos Asociado and Terminal de Contenedores de Cartagena, become important due to the length of their dock; likewise, due to the draft of its dock, the most important SPs are Oleoducto Central, Amerincan Port, Cerrejón Zona Norte, SP Puerto Nuevo and Puerto Brisa S.A; in terms of importance due to the number of cranes they have, the Cartagena container terminal, SP Regional

Cartagena, SP Regional Barranquilla, Port of Mamonal and San Andrés Port Society stand out; The SPs that stand out for having an interesting yard area are Cerrejón Zona Norte, Puerto Brisas and SP Puerto Nuevo, as well as the Cartagena Container Terminal, SP Regional Barranquilla have a larger area of warehouses.

When analyzing indicators related to port infrastructure, it is highlighted that, in indicators such as tons per linear meter of dock mobilized, Cerrejón Zona Norte, SP Puerto Nuevo, Cartagena Container Terminal and Cenit Transporte de Hidrocarburos present the highest indicator; likewise, in terms of the use of warehouses, the SP the Cartagena container terminal, Palermo Sociedad Portuaria and the Santa Marta regional SP present the highest indicators; Likewise, in the indicator Use of SP yards, the Port of Mamonal, Cartagena Container Terminal and Cartagena Regional SP stand out; in terms of operational efficiency, Cerrejón Zona Norte and Compañía de puertos asociados are the most outstanding.

Table 7. Model coefficients

Coefficient								
	Non-standardized coefficients		**Coef. typified**			**Correlations**		
Model	**ß**	**Typo error.**	**Beta**	**t**	**Say.**	**Zero Order**	**Partial**	**Semi-partial**
(Constant)	-31108664,512	15862526,615		-1,961	,086			
No. of Springs	-3183664,053	2987584,724	-,160	-1,066	,318	-,040	-,353	-,077
Dock Length in Mts	39999,563	14597,822	,375	2,740	,025	,255	,696	,197
Draft or Depth of Dock in Mts	-64115,311	836835,909	-,009	-,077	,941	,511	-,027	-,006
No. of Cranes	616272,046	303453,035	,248	2,031	,077	,193	,583	,146
Patio area m2	-4,125	28,013	-,015	-,147	,887	,121	-,052	-,011
Warehouse Area m2	-196,709	478,808	-,053	-,411	,692	-,038	-,144	-,030
Tons per linear meter of dock	3254,874	443,266	,805	7,343	,000	,916	,933	,529
Warehouse Utilization	-377630,057	363488,520	-,226	-1,039	,329	-,196	-,345	-,075
Use of courtyards	201609,510	220094,221	,133	,916	,386	-,011	,308	,066
Operational efficiency	287487,742	195690,647	,179	1,469	,180	,185	,461	,106

With regard to the impact of port infrastructure on the movement of cargo denoted by the port traffic of the SPs under analysis, it can be said that there is a correlation between the infrastructure variables analyzed and the movement of cargo, some to a greater extent than others, without saying that these are causal; therefore, a multiple regression analysis was performed, with the intention of looking for a link between variables (dependent and independent), which showed that there is statistically significant evidence of the relationship between these variables. On the other hand, the beta coefficient (ß) in the model shows that the independent variable that most explains the Tons. Mobilized is Ton. Per linear meter of dock with 0.805, followed by Dock Length and No. of cranes with 0.375 and 0.248 respectively, a situation that coincides with the Pearson correlation model used.

In future works, it is recommended to carry out more in-depth studies, expanding the number of variables and factors to determine the weight and incidence of each of them for the purposes of analysing port competitiveness.

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