ENVIRONMENTAL PERFORMANCE OF BRAZILIAN PORTS WITH CAPACITY FOR MODERNIZATION TO RECEIVE AND OPERATE POST-PANAMAX SHIPS

ADRIANE MARQUES PIMENTA
Geoscience Institute. Federal University of Minas Gerais. Av. Pres. Antônio Carlos. 6627 - Pampulha. Belo Horizonte - MG. 31270-901. Brasil
e-mail: adrioceano@hotmail.com
Orcid: 0009-0009-5328-2156

MARTÍ PUIG
Department of Chemical Engineering. Universitat Politècnica de Catalunya. Barcelona Tech. Diagonal 647. 08028 Barcelona. Catalonia. Spain
e-mail: marti.puig@upc.edu
Orcid: 0009-0007-1973-189X

DANIELE LAURA BRIDI MALLMANN
Oceanography Department. Federal University of Pernambuco. Av. da Arquitetura. s/n. Cidade Universitária. CEP: 50740-540 – Recife. Pernambuco. Brasil
e-mail: danielemallmann@gmail.com

RODRIGO ALBUQUERQUE NÓBREGA
Geoscience Institute. Federal University of Minas Gerais. Av. Pres. Antônio Carlos. 6627 - Pampulha. Belo Horizonte - MG. 31270-901. Brasil
e-mail: raanobrega@ufmg.br
Orcid: 0000-0001-7058-5903

ROSA MARI DARBRA
Department of Chemical Engineering. Universitat Politècnica de Catalunya. Barcelona Tech. Diagonal 647. 08028 Barcelona. Catalonia. Spain
e-mail: rm.darbra@upc.edu
Orcid: 0000-0003-4076-6898

ACKNOWLEDGEMENTS

This study was financed in part by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior - Brasil (CAPES) - Finance Code 001. Thanks to UPC and to National Council for Scientific and Technological Development (CNPq grant numbers 3124633/2018-2) for technical support.

Keywords

Environmental Performance Index, Brazilian ports modernization, Brazilian ports characteristics, Environmental management.

Abstract

It is widely known that ports are important infrastructures for the economic development, serving as pivotal entry points for commerce and having, significant strategic importance for countries. The Brazilian maritime sector comprises 35 public ports and 174 Private Use Terminals, and exist a pressing requirement for their modernization and adaptation, especially in view of the increasing size of post-Panamax ships. Out of these 209 ports, just a few have channel depths conducive for accommodating ships with drafts exceeding 15 meters. This highlights the imperative for upgrades to meet the evolving demands of the maritime industry. The objective of this study is to analyze the environmental performance of ports deemed suitable for the development to facilitate the reception and operation of post-Panamax ships. Consequently, emphasis was placed on ports located along the coastal region or major rivers. As a result, as part of this research a selection of 38 ports were scrutinized. The analysis of the selected ports was carried out through the Índice de Desempenho Ambiental (IDA), the most notorious environmental performance indicator used by the Brazilian Government to evaluate the environmental performance of ports, comprising 38 indicators into 4 categories: economic-operational, socio-cultural, physical-chemical and biological-ecological. The results confirm that there are some indicators that are very positive such as the existence of environmental licensing or the provision of qualified environmental professionals. However, there are some indicators with a low performance that should be addressed such as the implementation of emergency response plans and the provision of onshore power supply.

1 INTRODUCTION

It is widely known that ports are important infrastructures for the economic development and growth of coastal countries, serving as pivotal entry points for commerce and having, therefore, significant strategic importance for countries (Puig et al., 2022). The importance of ports for a country's trade and economic development is undeniable and it is particularly significant for Brazil, a nation known for its vast and diverse range of exports, leading by mineral commodities such as iron ore, and agricultural products such as soybean and corn. Brazilian ports play a crucial role in handling over 95% of the nations' exports and over 90% of imports (Cade, 2017). In 2021, Brazilian ports moved 1,115.5 million tons, establishing themselves as pivotal contributors to the country's economic and social development (ANTAQ, 2023).

According to information from the National Waterway Transport Agency (ANTAQ), the Brazilian maritime sector comprises 35 public ports and 174 Private Use Terminals (TUP). It is important to note that TUPs are distinct from merely private ports; instead, they serve as exclusive terminals for a particular company and are highly specialized in operating one type or a few types of products. Given their specialized nature, TUPs are inherently different from public ports that handle a multitude of product types. Consequently, any attempt to juxtapose TUPs with public ports would be inherently biased and unfair, particularly in the context of environmental performance. The inherent focus of TUPs on a specific product type contributes to a more efficient and environmentally conscious operation, as opposed to the multifaceted challenges encountered by public ports.

The Brazilian maritime sector needs modernization, recognizing the pressing need for a transformative shift. This transformation is crucial, as the current management model is entrenched in practices from the last century, impeding the country's port infrastructure fully realize its potential in the modern global economy (Maluf, 2022). One of the major challenges in the sector lies in the shallow depth and silting of the access channels, obstructing the navigation of increasingly larger vessels with greater drafts. Additionally, another significant concern is the constraint imposed on the largest and most vital ports by the proximity of large cities, limiting their expansion.

Despite the aforementioned benefits, ports are also associated with environmental and social impacts that cannot be ignored. In general, main port environmental impacts include the emission of several pollutants into the atmosphere including greenhouse gases (Tichavska & Tovar, 2015), particular matter, and other chemicals that have the potential to cause serious adverse effects, to both environment and human health (Široka et al., 2021). Other impacts include erosion and siltation, introduction of exotic species and loss of biodiversity (Silva et al., 2005, Porto & Teixeira, 2002). These impacts will depend on the scope and nature of the activities, products and services offered in the port area and will influence the port's environmental footprint (Puig et al., 2022).

According to Braga & Veloso-Gomes (2020), port environmental management initiatives have not yet been properly implemented in Brazilian public ports. In cases where such initiatives exist, they remain highly fragmented and lack a foundation in planning or environmental management techniques. Sustainable practices within Brazilian ports are often introduced either on the initiative of the port manager or in response to pressure from the stakeholders.

One of the environmental aspects that has been a growing concern for port facilities refers to their decarbonization. One way to reduce fuel consumption per volume of cargo transported is to increase the size of the vessels. It has been proven that larger ships, when compared to smaller ones, have an increase in fuel consumption that is lower than the corresponding increase in cargo capacity (Panagakos et al., 2019; Lindstad et al., 2012; Chang and Jhang, 2016). Indeed, meeting the needs of vessels of such considerable size requires, on the one hand, a compatible water depth for operation and maneuver and, on the other hand, berths-ship docking area for accommodating large ships, and terminals capable of handling enormous quantities of goods, including hundreds of hectares of land with infrastructure for roads and railways and warehouses (Notteboom et al., 2022).

As aforementioned, the environmental impacts caused by the operation of ports can be very varied and therefore, tools are developed to monitor these impacts. One effective approach to assess port environmental impacts and evaluate the efficiency of mitigation measures is using environmental indicators. Environmental Performance Indicators (EPIs) are important to evaluate environmental performance of port authorities and to track progress towards continuous improvement (Donnelly et al., 2007). An example of index comprising port indicators is the Port Environmental Index (PEI). It aims to integrate all the main environmental aspects of ports, such air emission, waste production, water pollution, noise, light, and odor pollution, into one metric and it was applied in four pilot ports: Port of Bordeaux (France), Port of Monfalcone (Italy), Port of Thessaloniki (Greece) and Port of Piraeus (Greece) (Široka et al., 2021).

In Brazil, the most notorious environmental performance indicator used by the Brazilian Government to evaluate the environmental performance of ports (both public and private) is the Environmental Performance Index, called IDA (acronym for its initials of *Índice de Desempenho Ambiental*). IDA was developed based on a Cooperation Agreement between ANTAQ and the Federal University of Brasilia (UnB), with the aim of developing a method to calculate a performance index covering environmental issues in port facilities. The indicators that IDA takes into account are related with some of the Sustainable Development Goals (SDGs), such as: Affordable and clean energy (nº 7), Industry, innovation and infrastructure (nº 9), Responsible, consumption and production (nº 12), Climate action (nº 13), Life below water (nº 14) and Life on land (nº 15).

The maritime sector plays a crucial role in expanding the Brazilian economy, contributing to trade, job creation, and technological advancements. Therefore, there exists a pressing issue for modernizing port operations while ensuring environmental sustainability. For this reason, the objective of this study is to analyze the environmental performance of ports deemed suitable for development to facilitate the reception and operation of post-Panamax ships.

2 METHODOLOGY

This section presents the sample ports that have been considered for this research and their characteristics. It also includes the explanation of the adaptation made to the IDA methodology to assess the environmental performance of the selected Brazilian ports.

2.1 Sample of selected ports and their characteristics

As aforementioned, in Brazil, there are 209 port facilities registered with ANTAQ, being 17% of them public and 83% terminals for private use (TUP). For this study a set of 38 ports was selected, considering the ports deemed suitable for development to facilitate post-Panamax ships, which are responsible for 45,6% of the 1,115.5 million tons handled in the country in 2021. Figure 1 displays all the Brazilian port installations, highlighting in red dots the selected 38 ports.

Figure 1: Location of Brazilian ports and selected ports within Brazil regions.

The main characteristics of the selected 38 ports are presented below. To do so, information regarding port movement, type of cargo transported, ship draft, dredging requirement, region and location was selected from ANTAQ website[1] for the mentioned ports.

Among the 38 ports selected in this study, 79% are public ports and 21% are ports for private use (TUP), and there is a need for dredging to maintain depth in 71% ports, whereas 29% do not require it. Among the dredging-active ports, 74% engage in occasional dredging activities, such as channel deepening, while 26% conduct more frequent dredging to sustain channel depth.

Ports predominantly favor estuarine locations (Figure 2), with artificial coasts ranking second (29%), followed by protected coasts and rivers, each accounting for 16%.

[1] https://web3.ANTAQ.gov.br/ea/sense/index.html

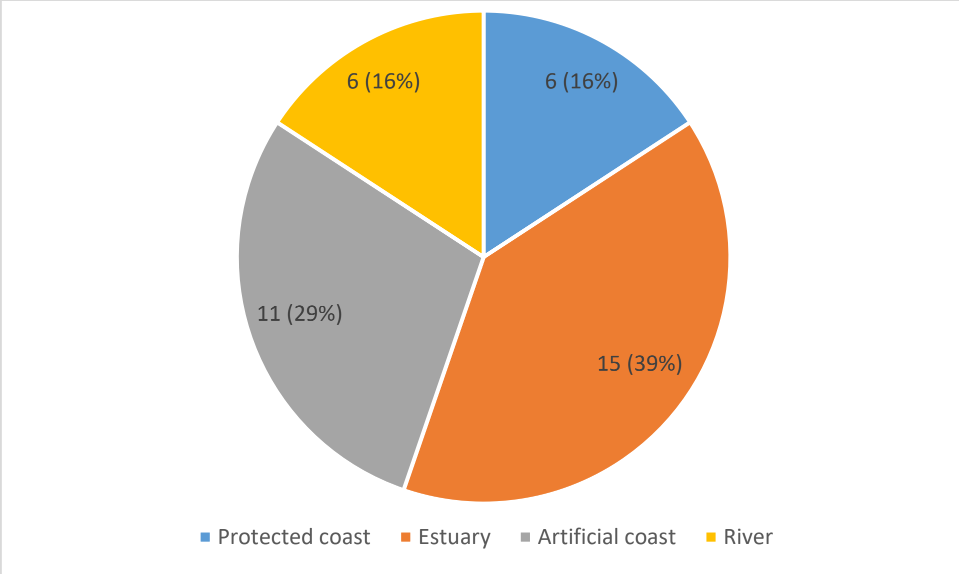

Figure 2: Location of ports.

As per the land use typology, 63% of the ports are surrounded by cities, 29% are surrounding protected areas, mangroves or forests, 5% agricultural areas and 3% is located in the beach (Figure 3). It is noteworthy to consider the historical context of ports in Brazil concerning this matter. The earliest ports emerged and evolved alongside the development of cities, leading to a current scenario where they are closely connected, giving rise to significant conflicts in the relationship between ports and cities. The complex dynamics between ports and cities, especially for older and more traditional ports, are well-documented. Studies highlight examples, such as the anticipated partial deactivation of the Port of Vitória, as a consequence of conflicts with the city (Campos, 2023). Most of the port facilities in Brazil's colonial cities, such as the Port of Vitória, had their location determined by geographic attributes given by relief, climate and hydrography, constituting natural ports per excellence. Undoubtedly, the landscape matrix, delineating the geographic profile of a natural port, distinctly shapes the territorial occupation, enhancing the scenic attributes of the Port of Vitória (Campos, 2023).

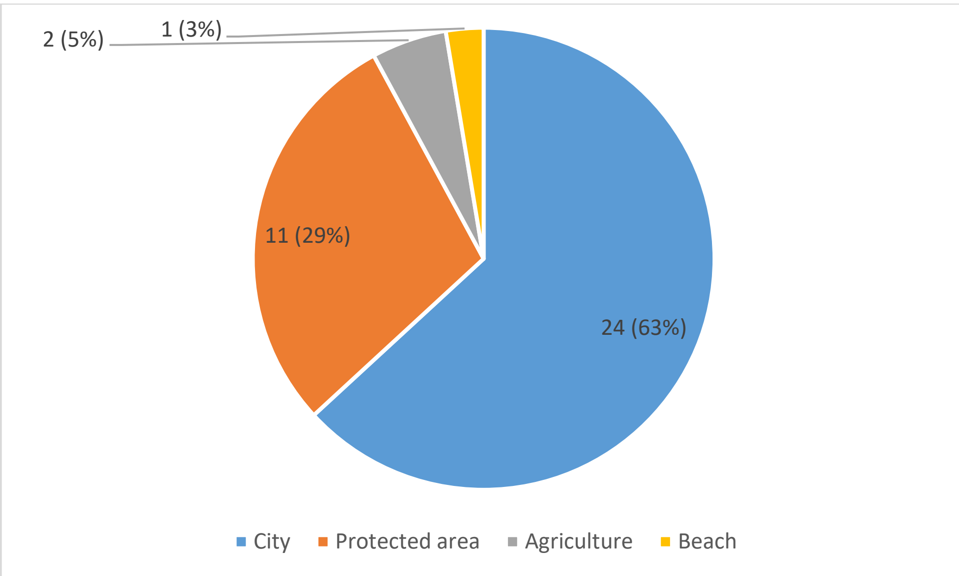

Figure 3: Land use of ports.

Regarding the maximum draft allowed, 24% (9 ports) allow a maximum draft of up to 10 meters, 55% (21) allow a draft between 10 and 15 meters, 16% (6) allow a draft between 15 and 20 meters, and 5% or 2 ports present safe depth for ships with a draft of more than 20 meters.

Finally, as for the region, 12 ports are located in the Northeast region, 11 in the Southeast regions, 8 in the South region and 7 in the North region.

2.2 Brazilian environmental performance index (IDA)

The IDA is the most significant indicator on Brazil's port environmental performance. It comprises a total of 38 indicators, which are divided into 4 categories (economic-operational, socio-cultural, physical-chemical and biological-ecological) and 13 subcategories, as can be seen in Figure 4.

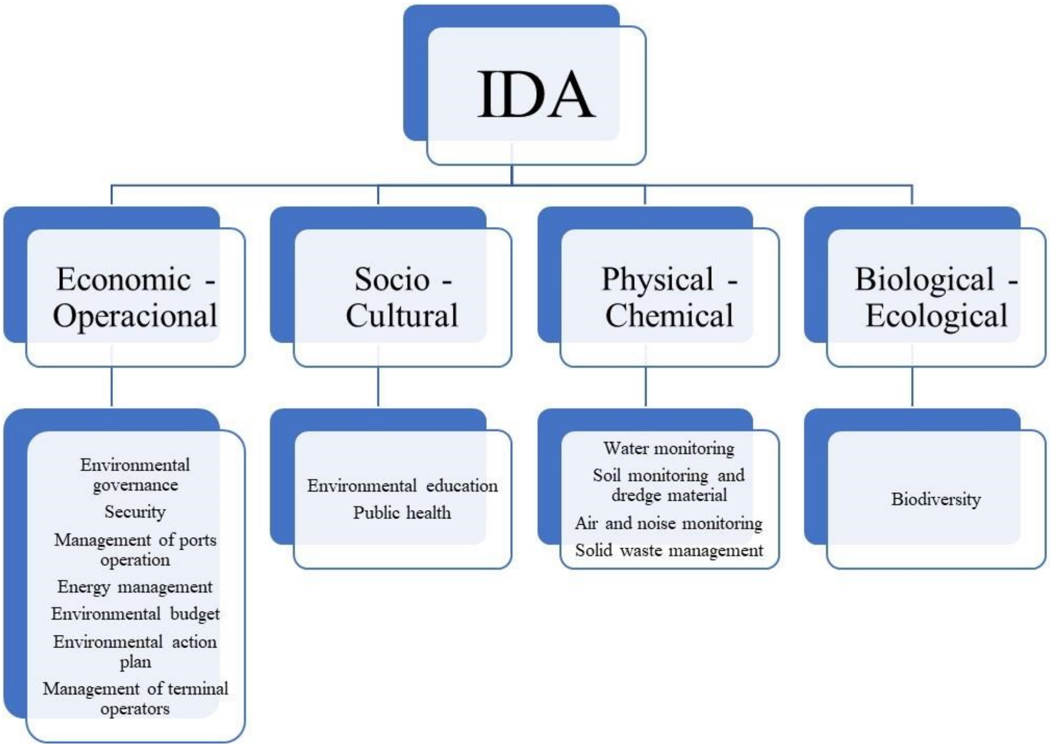

Figure 4: Main categories and subcategories of IDA.

The IDA gives a score ranging from 0 (worst performance) to 100 (best performance) (ANTAQ, 2021). Administrators of the ports with the highest scores use the IDA as a "green certificate seal" to publicize the port's environmental management and the attractiveness of international maritime trade (Brito, 2011). There are two categories of port awards: the ports with the three best results of the year receive awards, as well as the ports that showed a significant improvement in their results compared to the previous year.

The IDA survey permits responses at different levels. There exist two types of questions with different answers' ranges: the first type offers answers which range from N1 (worst scenario) to N3 (best scenario), and the second type provides answers that range from N1 (worst scenario) to N5 (best scenario). For the present analysis, N1 responses were labeled as "N" as the port does Not comply the specific indicator, while the best responses (N3 or N5) were marked as "C" as the port Complies with the specific indicator, as illustrated in Table 1. Intermediate positions between these two responses were considered "P" as Partial. Subsequently, the percentages for each of these potential responses were computed, and those indicators with a majority of "C" responses among ports were indicative of higher performance.

In Option 2 there are 3 levels of partiality that can be reached (N2, N3 and N4) between the worst-case scenario (N1) and the best-case scenario (N5). This bias can range from an initial action to meet the indicator to actions that almost fully meet the indicator but cannot yet be considered as fully met. In order to be able to compare these categories with Option 1, in which there is only N2 as Partial, N2, N3 and N4 (Option 2) were standardized as partial, regardless of how much closer this partiality is to the worst or best scenario.

Option 1: from N1 to N3	Equivalence	Option 2: from N1 to N5	Equivalence

N1	No (N)	N1	No (N)
N2	Partially (P)	N2	Partially (P)
N3	Comply (C)	N3	Partially (P)
-	-	N4	Partially (P)
-	-	N5	Comply (C)

Table 1. Possible IDA responses to the indicators and the equivalence adopted.

Information related to the Environmental Performance Index (IDA) was collected at the IDA website[2]. The reported data comprises information from 2012 (when IDA monitoring began) to 2021 (last year with available data). A comparison was undertaken across various years to observe the evolution of IDA. Between 2012 and 2015, results were reported semi-annually, and from 2016 onward, the reporting frequency shifted to an annual basis. It is noteworthy to mention that ports designated for private (TUPs) use began implementing IDA in 2017. It should be noted that this article does not intend to make a comparison between organized ports and TUPs. TUPs are highly specialized ports, which generally transport only one type of product, making the comparison with organized ports which generally transport all types of products unfair in relation to environmental performance. This paper has given particular emphasis on the 2021 results.

3 RESULTS AND DISCUSSION

3.1 IDA trends over the years

Regarding the IDA analysis, there has been a discernible evolution in results since its inception in 2012 until 2021. On average, the results ranged from 59.3 in 2012 to 77.5 in 2021 (Figure 5). This progressive increase in the IDA results has been consistently observed since the early years of the indicator's application. This a trend was previously reported by Rocha (2018), who analyzed the results until 2016.

In the overall trend, changes in the IDA are noticeable over the years. Before 2016, the average IDA for monitored ports stayed around 60 points. In 2017 and 2018, there was a shift to the mid-60s, reaching 70 points in 2019. In 2020, there was significant progress, with results nearing 80, despite a slight decrease in 2021. The increase of IDA values along the years may be attributed to factors such as the environmental regulations and compliance, investment in sustainable practices and public awareness and pressure. The decline in 2021 may be partially attributed to the disruptions caused the COVID-19 pandemic. The pandemic might have led to delays or disruptions in planned environmental initiatives or investments, thereby impacting the overall environmental performance of ports.

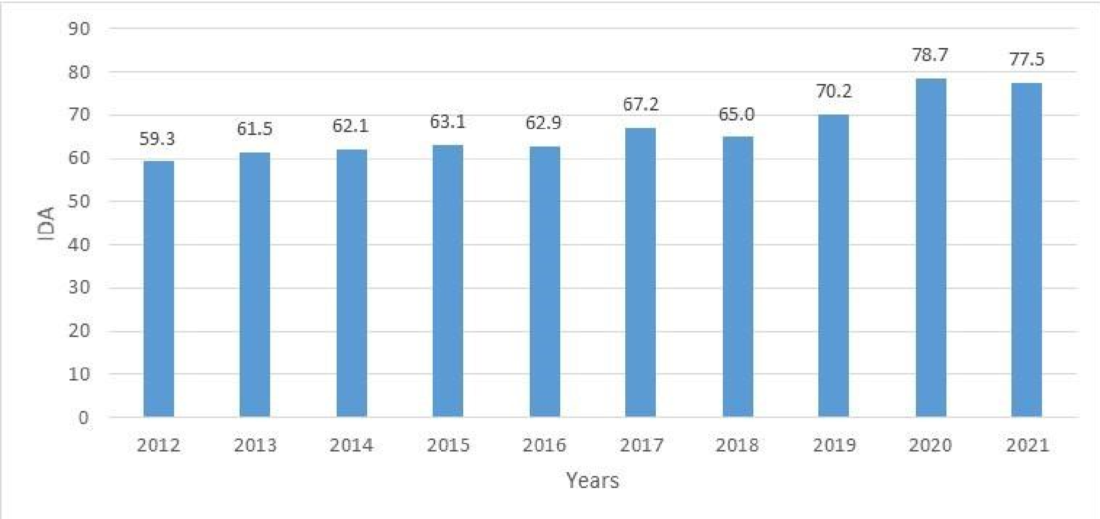

Figure 5: Evolution of IDA over the years.

[2] http://web.ANTAQ.gov.br/ResultadosIda/

3.2 Results by port characteristics (year 2021)

The forthcoming results presented are those of the year 2021, selected for their status as the most current and up-to-date available data. When looking at Figure 6, it can be seen that the smaller ports, which handle less than 5 million tons per year, had the lowest IDA when compared to the larger ports. This could be attributed to the fact the bigger ports, in general, have more resources than small ports and therefore they can invest more in improving their environmental performance. In addition, bigger ports have more stakeholders that can press the port to improve their environmental situation.

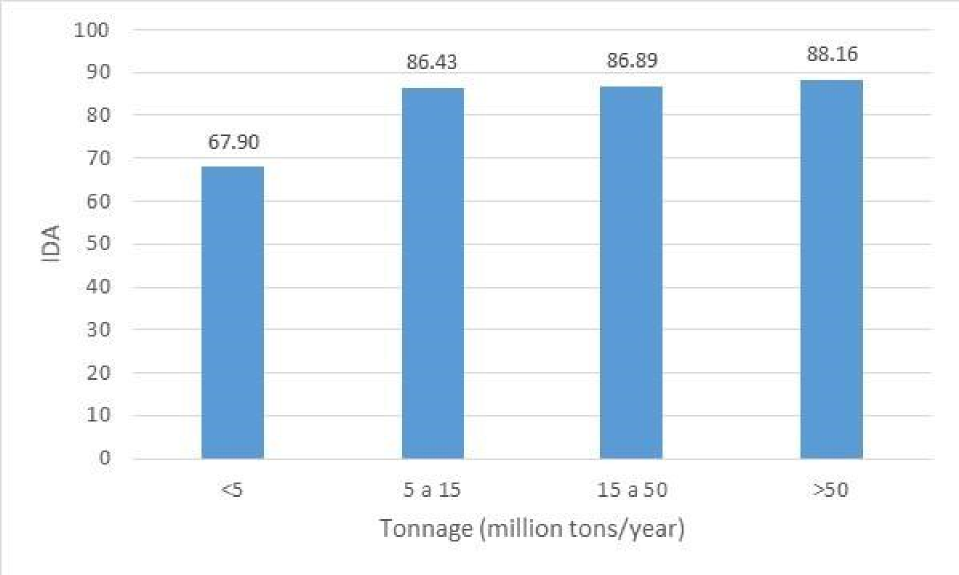

Figure 6: IDA results per tonnage in 2021.

Similar trends are observed in the case of the draft, ports capable of operating ships with drafts exceeding 20 meters demonstrated the best results, while smaller ports exhibited lower performance (Figure 7). This choice is influenced by the notion that IDA may strongly reflect political willingness and the management practices of port authorities, therefore, ports with more resources tend to excel. It may also be related to standards imposed by lessee terminals and shipowners, who possess advanced environmental management practices and certifications that require maintenance.

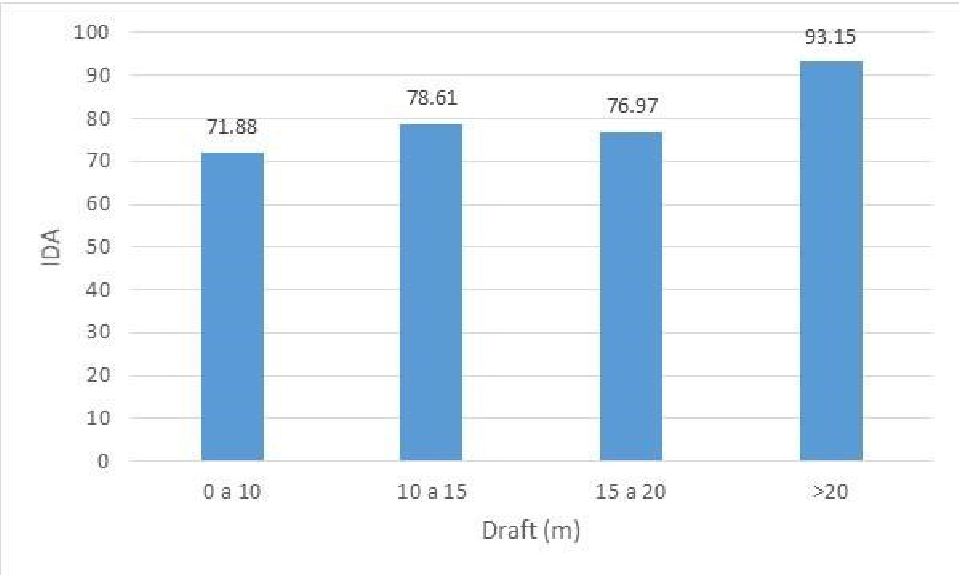

Figure 7: IDA results per draft in 2021.

Ports located in the South region presented the best performance results, and the worst result occurred in the Northeast region. In the same sense, Rocha (2018) analyzed the results of IDA between the first half of 2012 and the first half of 2016 using Duncan test to compare averages. The findings demonstrated that the environmental performance of ports in the South/Southeast macro-region surpassed that of ports in the North/Northeast macro-region (Figure 8). This could be attributed since the first regions highlight for their higher financial development., which mean that they can invest more resources in improving their ports environmental performance.

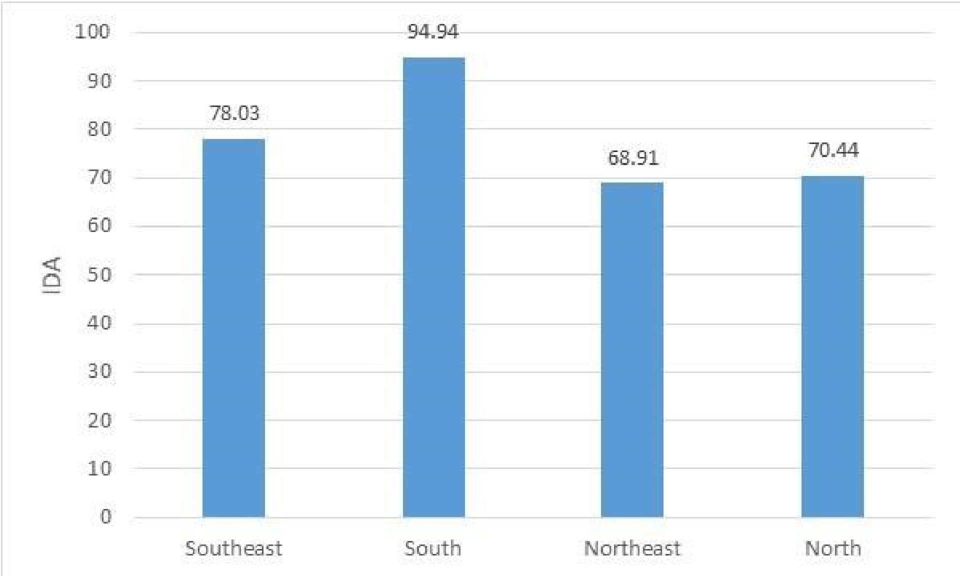

Figure 8: IDA results per Brazil's region in 2021.

In relation to location, the best performance was observed in ports located in estuarine areas, while ports located in rivers reached worst performances (Figure 9). Ports located on rivers are predominantly found in the northern region, which may justify this poor performance. The more traditional, older ports with large cargo movements, such as the ports of Santos, Paranaguá, Salvador, Antonina, Vitória, Sao Francisco do Sul, Rio Grande and Itaqui, are examples of ports located in estuaries and involving a large number of stakeholders who may be putting pressure on these ports to improve their environmental performance index. Furthermore, estuaries are sensitive areas as they are transition environments between the coastal and continental regions and, therefore, are complex environments that involve a rich diversity of fauna and flora, they are natural and very sensitive nurseries, which can lead to greater demands on environmental agencies to these ports.

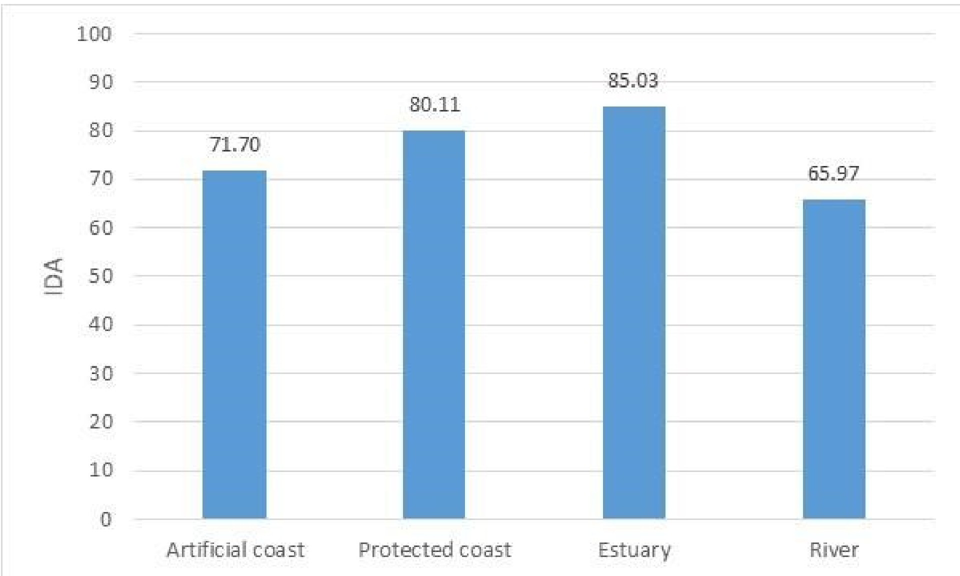

Figure 9: IDA results per location in 2021.

Regarding land use, the best IDA results were obtained in ports located in natural areas (e.g. mangroves, forests), and the worst in ports located in areas with agriculture vocation (Figure 10).This result may reflect environmental licensing, as ports located in natural areas are likely to have stricter licensing in relation to the mitigation and compensation of environmental impacts.

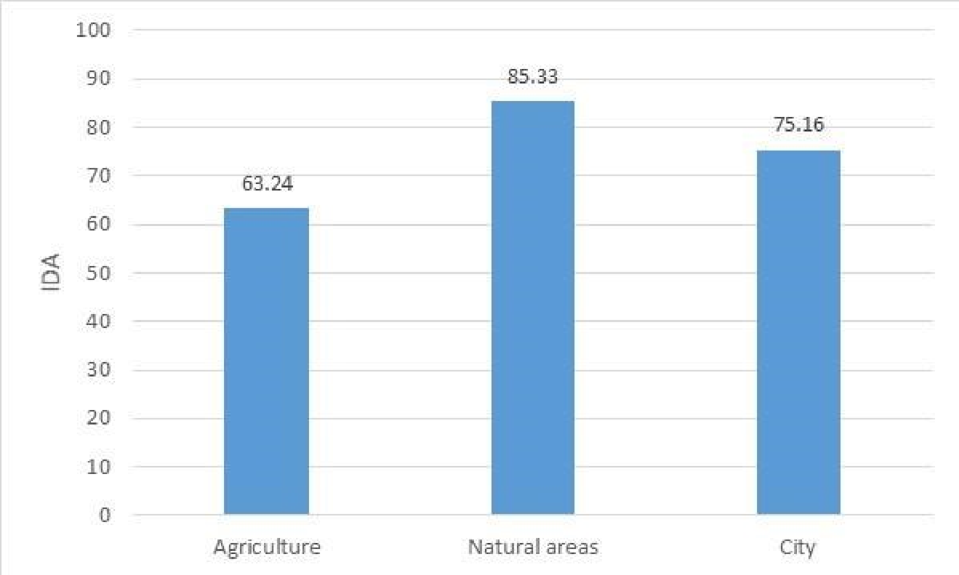

Figure 10: IDA results per land use in 2021.

3.3 Analysis by IDA categories (year 2021)

In this section, the IDA results are presented in accordance with the four categories mentioned in Figure 4, analyzing the results of the year 2021.

3.3.1 Economic-Operational Category

Within the first subcategory, *Environmental Governance*, the indicator *existence of an Environmental licensing* is the one with the highest number of ports that fully comply this indicator (91.9%) (Table 2). Notably, environmental licensing is guided by specific legislative references, while the remaining indicators are more influenced by external pressure from involved stakeholders and port authorities. In 2013, 62.2% of ports had an environmental operating license, 16.2% were in the process of obtaining one and 21.6% did not have a license neither a process for obtaining one. For instance, at that time, the port of Santos, the largest port in the country, was operating with pending environmental license, since it was in the process of obtaining it (Roos e Kliemann Neto, 2017). This observation highlights that, within a brief timeframe, the majority of ports have successfully adapted, driven either by legal mandates or intensified environmental awareness. Within the same subcategory, 81% of ports confirmed that have the *provision of environmental professionals above the minimum required*. This shows that Brazilian ports are hiring more specialized professionals, since Figueiredo *et al.* (2016) found, several years ago, that finding qualified labour in ports was challenging. The *development of an environmental audit within the two previous years* was conducted in almost 84% of ports. This is also proving that Brazilian ports are willing to monitor their environmental performance.

Categories	Subcategories	Indicators	C (%)	P (%)	N (%)
Economic-operational	Environmental governance	Existence of an environmental licensing	91.9	8.1	0.0
		Provision of environmental professionals above the minimum required	81.1	10.8	8.1
		Provision of environmental training to more than 50% of the environmental department personnel in the last year	78.4	8.1	13.5

Categories	Subcategories	Indicators	C (%)	P (%)	N (%)
		Development of an environmental audit within the two previous years	83.8	10.8	5.4
	Security	Existence of an oceanographic / hydrological and meteorological database updated biannually	70.3	2.7	27.0
		Existence and implementation of all risk prevention and emergency response plans	37.8	54.1	2.7
		Non-occurrence of environmental accidents in the last year	73.0	27.0	0.0
	Port operations management	Comply with all the ship waste removal actions required	70.3	18.9	10.8
		Comply with all the container operations with dangerous goods actions required*	68.4	15.8	15.8
	Energy management	Comply with all the energy consumption reduction actions required	48.6	13.5	37.8
		Generation of clean and renewable energy by the port	37.8	18.9	43.2
		Provision of on-shore power supply for ships	0.0	29.7	70.3
	Environmental budget	Comply with all the environmental budget actions required	78.4	18.9	2.7
	Environmental action plan	Disclosure of port environmental information through the website	70.3	8.1	21.6
		Development and implementation of an external environmental action plan with other port stakeholders (public organizations, port companies, etc.)	43.2	8.1	48.6
		Development and implementation of an internal port environmental action plan	62.2	5.4	32.4
		Achievementof at least two management systems certifications (e.g. ISO 9001, ISO 14001, ISO 45001, ISO 50001)	29.7	10.8	59.5
	Management of terminal operators*	Control of the environmental performance of terminal operators by the port authority	96.1	3.8	0.0
		Existence of an environmental licensing in all companies	92.3	7.7	0.0
		Existence of an emergency plan in all the terminal operators	84.6	11.5	3.8
		Development of an environmental audit in all the terminal operators	69.2	19.2	11.5
		Existence of a solid waste management plan in all the terminal operators	84.6	15.4	0.0
		Achievement of at least two management systems certifications (e.g. ISO 9001, ISO	30.8	42.3	26.9

Categories	**Subcategories**	**Indicators**	**C (%)**	**P (%)**	**N (%)**
		14001, ISO 45001, ISO 50001) in all the terminal operators			
		Provision of an environmental education program in all the terminal operators	69.2	15.4	15.4

Table 2. IDA results per Economic-Operational category (2021).
*Indicators answered only by public ports.
C= Comply. P= Partially. N= No.

Within the *Security* subcategory, *the existence of an oceanographic/hydrological and meteorological database updated biannually* was fully met by more than 70% of ports facilities. This indicator was difficult to meet by ports in the past (Ramalho, 2015). The indicator *existence and implementation of all risk prevention and emergency response plans* was implemented only by 38% of ports facilities. This is an aspect that Brazilian ports should improve since it is essential to ensure the port safety. Concerning the indicator *of non-occurrences of environmental accidents*, 73% of ports did not have any accident in 2021.

Within the *Energy management* category, the indicator *comply with all the energy consumption reduction actions required* was fully implemented in 2021 by 49% of ports facilities. In this line, Calcerano and Hilsdor (2021) reported that the practices observed in terminals to reduce energy consumption and carbon emissions were more related to operational performance than to sustainability. The *generation of clean and renewable energy* indicator was fully complied by 38% of both TUPs and public ports, indicating that this remains as a challenging indicator to fulfill across various ports. It is noteworthy that the IDA has been applied since 2012 without changing the indicators. Notably, some ports have already managed to improve to meet the index along this period. However, in the case of the indicator of *provision of on-shore power supply* for ships, within the *Energy Management* subcategory, no port has met it. In general, Brazilian ports do not make investments that would not bring a financial return, and this indicator is considered to be too expensive to apply without any economic return.

Within the *Environmental action plan* subcategory, the indicator *disclosure of port environmental information through the website* stands out as the best performing indicator with 70% of compliance. The *development and implementation of an external environmental action plan with other port stakeholders* is a difficulty for implementation in 2021 and only 43% of ports comply with this indicator (48% public and 25% private); however, the *development and implementation of an internal port environmental action plan* is a priority for 62% of ports. The *achievement of at least two management systems certifications* stands out as a negative aspect, with almost 60% of the ports analyzed not having them. Only 30% of the ports have at least two certificates.

Finally, the subcategory on *Management of terminal operators* only applies to public ports since TUPs are not tenants. The indicator on *control of the environmental performance of operators by the port authority* presented satisfactory results, since 96% of public ports responded full compliance with this indicator. The *existence of a solid waste management plan in all the terminal operators* occurs in 85% of public ports.

3.3.2 Socio-Cultural

The indicator *comply with all the environmental education actions required* was met by more than 70% of ports (Table 3). The indicator *comply with at least four health promotion actions required* was met by 84% of analyzed ports.

These results show that ports apparently have no difficulties in applying the indicators in this category, with the exception of the *development, implementation and update of a port contingency plan*, with. only 52% of the public ports responded positively.

Categories	Subcategories	Indicators	C (%)	P (%)	N (%)
Socio-cultural	Environmental education	Comply with all the environmental education actions required	70.3	18.9	10.8

Categories	Subcategories	Indicators	C (%)	P (%)	N (%)
	Public health	Comply with at least four health promotion actions required	83.8	16.2	0.0
		Development, implementation and update of a public health port contingency plan*	51.7	31.0	17.2

Table 3. IDA results per Socio-cultural category (2021).
*Indicators answered only by public ports.

3.3.3 Physical-Chemistry

Within the subcategory on water monitoring, the indicator *existence and implementation of an environmental monitoring program for water quality*, Ramalho (2015) found that only 8% of ports met this indicator for the period between 2012 and 2015. In 2021 it was met by 59% of ports (Table 4), showing a clear improvement in a few years. The indicator *existence of a rainwater drainage, and monitoring and treatment of the rainwater quality* was complied by 46% of ports.

Within the subcategory on air and noise monitoring, the *existence of air emissions inventory and air quality monitoring, and implementation of mitigation actions* remained a challenge for ports, with only 46% of ports fully meeting this criterion.

Finally, the *existence and implementation of a solid waste management plan in the port* also continued to be met by 73% of ports facilities.

Categories	Subcategories	Indicators	C (%)	P (%)	N (%)
Physical-Chemistry	Water monitoring	Existence and implementation of an environmental monitoring program for water quality	59.5	35.1	5.4
		Existence of a rainwater drainage, and monitoring and treatment of the rainwater quality	45.9	48.6	5.4
		Existence of a water reduction and reuse program and implementation of at least two actions	59.5	16.2	24.3
	Soil and dredged material monitoring	Existence of environmental monitoring of dredged area and disposal area of dredged material*	54.0	8.1	10.8
		Non-existence environmental liabilities or already remedied	70.3	27.0	2.7
	Air and noise monitoring	Existence of air emissions inventory and air quality monitoring (gases and particulates), and implementation of mitigation actions	45.9	35.1	18.9
		Existence of an inventory of noise emissions and implementation of periodic noise monitoring	64.9	16.2	18.9
	Solid waste management plan	Existence and implementation of a solid waste management plan in the port	73.0	27.0	0.0

Table 4. IDA results per Physical-Chemistry category (2021).

3.3.4 Ecological-Biological

The indicator *existence of fauna and flora inventory and implementation of periodic monitoring* is carried out by 60% of ports, while the *development, implementation and update of a synanthropic[3] animals monitoring program and submission quarterly to the health authority* is carried out by 73% of ports facilities. (Table 5). Finally, the *existence of exotic/invasive species inventory and implementation of actions for their control* are entirely supported by 49% of ports.

Categories	Subcategories	Indicators	C (%)	P (%)	N (%)
Ecological-Biological	Biodiversity	Existence of fauna and flora inventory and implementation of periodic monitoring	59.5	18.9	21.6
		Development, implementation and update of a synanthropic animals monitoring program and submission quarterly to the health authority	73.0	16.2	10.8
		Existence of exotic/invasive species inventory and implementation of actions for their control	48.6	21.6	29.7

Table 5. IDA results per Ecological-Biological category (2021).

Although IDA is a widely used and disseminated tool for monitoring the environmental management of Brazilian ports, this indicator also presents some limitations, difficulties and disadvantages in its use. These include prolonged dissemination periods for publishing the results, the lack of standardized response criteria impeding ease comparisons, and the absence of regular updates to the applied criteria.

4 CONCLUSION

By analyzing the characteristics of the selected 38 ports that are deemed to be expanded in Brazil, it is found that most of them are surrounded by large cities or areas of environmental interest (forests, mangroves, estuaries), this means that they find themselves strangled around the city. Since there is a need for the modernization of the countries' ports, this shows that this future modernization and development may become very challenging, both in the search for greater depths and in the need to expand areas, taking into account that many of them are completely surrounded by large cities.

As noted, the IDA average has been evolving each year, demonstrating the ports commitment and interest in taking measures to mitigate their impacts. In this sense, some indicators seem to be easier for ports to achieve. As an example, the indicators with the best results are: i) existence of environmental licensing of the ports, ii) development of an environmental audit within the two previous years, iii) comply with at least four health promotion actions required, iv) provision of environmental professionals above the minimum required, v) control of the environmental performance of terminal operators. In general, it has been seen that the results for the terminal operators are better than for the port authorities.

The questions asked in the IDA questionnaire have never been modified. However, in these 10 years during the application of the IDA, ports are still finding challenging to implement actions to meet all the indicators. It is relevant to mention the indicator of the provision of on-shore power supply for ships, which is not met by any of the ports analyzed. It could be attributed to several factors, such as infrastructure costs (installing on-shore power supply infrastructure is expensive and ports may be cautious to invest in the necessary equipment and facilities, especially if they do not see an immediate return on investment or if there are other pressing infrastructure needs) and space constraints (ports may have limited space for additional infrastructure and installing on-shore power supply systems may require significant space). In addition, voluntary management certifications, such as the implementation of ISO 9001, ISO 14001, ISO 45001 or ISO 50001, is also poorly adhered by port authorities and terminals operators. Port authorities and terminal

[3]An organism that lives near and benefits from humans and their environmental modifications.

operators may face resource constraints, making it challenging to allocate the necessary funds and personnel for certification processes. The indicator existence and implementation of all risk prevention and emergency response plans is poorly implemented by only 38% of ports facilities, and efforts should be posed in this topic since it is essential to ensure the port safety. Additionally, there are other indicators with a low performance, highlighting the generation of clean and renewable energy by the port and the existence of air emissions inventory and air quality monitoring.

By undertaking this research, it has been found that Brazilian ports have difficulties in implementing measures to mitigate environmental impacts, whether due to the lack of financial resources or specialized human resources, also justified by Calcerano & de Castro Hilsdorf (2021). The difficulty in implementing indicators that require greater financial investment highlights the challenge faced by Brazilian ports in adapting to the new reality of global navigation, particularly with the proliferation of increasingly larger ships. The demand for accommodating these larger vessels necessitates not only substantial investments in port infrastructure but also a comprehensive renovation of operational practices and the incorporation of advanced technologies to enhance overall efficiency. This multifaceted challenge highlights the critical need for strategic planning, collaboration among stakeholders, and a concerted effort to address the economic, technological, and regulatory aspects involved in transforming Brazilian ports into modern, adaptable, and competitive hubs capable of handling the evolving demands of the maritime industry. Without overcoming these challenges, Brazilian ports may face constraints in fully capitalizing on the opportunities presented by the shifting dynamics of global shipping, potentially impacting their competitiveness and ability to meet the evolving needs of international trade.

5 REFERENCES

Agência Nacional de Transportes Aquaviários. Estrutura e indicadores: Estrutura do IDA. In: Ministério dos Transportes. *Portal Gov.br* [online]. 2021. [Accessed: February, 2024]. Available at: https://www.gov.br/antaq/pt-br/assuntos/meio-ambiente/indice-de-desempenho-ambiental-ida-1/estrutura-e-indicadores.

Agência Nacional de Transportes Aquaviários. *Painel Estatístico Aquaviário*. [online]. 2024. [Accessed: February, 2024]. Available at: https://web3.ANTAQ.gov.br/ea/sense/index.html. Accessed in 05/02/2024.

Braga, R. C. M. S.; Veloso-Gomes, F. Environmental licensing as an instrument for the environmental management of Brazilian public ports. *Sustainability* [online]. Switzerland, 2020, vol. 12, no. 6, 2357, [Accessed: February, 2024]. Available at: https://doi.org/10.3390/su12062357

Budiyanto, M. A.; Adha, A.; Prayoga, P. H. N. Distribution of energy efficiency design index for tankers in Indonesia. *Energy Reports* [online]. 2022, vol. 8, Supple. 15, p. 170–176. [Accessed: February, 2024]. Available at: https://doi.org/10.1016/j.egyr.2022.10.089

Conselho Administrativo de Defesa Econômica. Departamento de Estudos Econômicos. *Mercado de serviços* portuários [online]. Brasilia: Cade, 2017. [Acessed: 08 de agosto de 2023]. Available at: https://doi.org/10.52896/dee.cc1.017

Calcerano, T. A.; de Castro Hilsdorf, W. *Sustainability practices in container terminals in Brazil*. production, 2021, Prod. 31, p. 1–13. [Accessed: February, 2024]. Available at: https://doi.org/10.1590/0103-6513.20200113

Campos, M. M.; Vasconcelos, F. N. *Porto na cidade: questões expandidas* [online]. Edufes, 2023, 266 p: il; 21 cm. Coleção Pesquisa Ufes; 59. ISBN 978-85-7772-549-6

Chang, C.C.; Jhang, C. W. Reducing speed and fuel transfer of the Green Flag Incentive Program in Kaohsiung Port Taiwan. *Transportation Research Part D: Transport and Environment*. [online]. 2016, vol. 46, p.1-10. [Accessed: July, 2023]. Available at: https://www.sciencedirect.com/science/article/abs/pii/S1361920916000365.

Christodoulou, A. Maritime environmental performance indices: Useful tools for evaluating transport supplier environmental performance? *WIT Transactions on the Built Environment* [online]. Wit Press, 2019, vol. 187. P. 187–198. [Accessed: February, 2024]. Available at: https://doi.org/10.2495/MT19017

Clean Shipping Index. *Verification Guidelines 2018* [online]. Gothenburg. Sweden: Clean Shipping Index, 2018. [Accessed: February, 2024]. Available at: https://www.verifavia-shipping.com/uploads/files/2018-05-03-Verification-Guidelines.pdf

Costa, H. G. Introdução ao método de análise hierárquica: análise multicritério no auxílio à decisão. Niterói: H.G.Costa, 2002. 122 p. [Accessed: February, 2024]. Available at: http://www.din.uem.br/sbpo/sbpo2004/pdf/arq0279.pdf

Cunha, D.R.; Pereira, N.N.; Moneva, J.M. Port sustainability initiatives: a study of brazilian public ports. *Revista Gestão e Secretariado* (GeSec) [online]. São Paulo: 2023, vol. 14. no. 8, p. 12674-12693. [Accessed: February, 2024]. Available at: https://doi.org/10.7769/gesec.v14i8.2558

Donnelly, A.; Jones, M.; O'Mahony, T.; Byrne, G. Selecting environmental indicator for use in strategic environmental assessment. *Environmental Impact Assessment Review* [online]. 2007, vol. 27, no. 2, [Accessed: February, 2024]. Available at: https://doi.org/10.1016/j.eiar.2006.10.006

ESI. Environmental Ship Index. [Accessed: February, 2024]. Available at: https://www.environmentalshipindex.org/

Lindstad, H.; Asbjørnslett, B. E.; Strømman, A. H. The importance of economies of scale for reductions in greenhouse gas emissions from shipping. *Energy Policy* [online]. 2012, vol. 46, p. 386-398. [Accessed: May, 2024]. Available at https://doi.org/10.1016/j.enpol.2012.03.077

Maluf, N. B. A desestatização dos portos públicos brasileiros e perspectivas para a infraestrutura. In: Nico Vasconcelos, F.; Cardoso, L. *Porto, mar e comércio internacional. Por elas*. [online]. Vitória: Editora Milfontes, 2022, 354 p., [Accessed: May, 2024]. Available at: https://editoramilfontes.com.br/acervo/COM%C3%89RCIO_INTERNACIONAL_%20POR_ELAS_SITE.pdf. ISBN: 978-65-5389-043-5.

Notteboom. T.; Pallis, A.; Rodrigue, J.P. *Port Economics. Management and Policy*. New York: Routledge, 2022, 690 pages. ISBN 9780367331559.

Panagakos, G.; Pessôa, T. S.; Dessypris, N.; Barfod, M. B.; Psaraftis, H.N. Monitoring the carbon footprint of dry bulk shipping in the EU: An early assessment of the MRV regulation. *Sustainability* [online]. 2019, vol. 11, no. 18, 5133; [Accessed: May, 2024]. Available at: https://doi.org/10.3390/su11185133.

Pereira, B L.; Silva, E S.; Ferreira, T G.; Gonçalves, A L. "Green Ports" and the port of Santos. In: *SBE16 Brazil & Portugal sustainable urban communities towards a nearly zero impact built environment*. 2016, p. 1183-1192. ISBN: 978-85-92631-00-0.

Porto, M. M.; Teixeira, S. G. *Portos e meio ambiente*. São Paulo: Aduaneiras, 2002.

Puig, M.; Azarkamand, S.; Wooldridge, C.; Selén, V.; Darbra, R. M. Insights on the environmental management system of the European port sector. *Science of the Total Environment* [online]. 2022, vol. 806, part 2, 150550, [Accessed: May, 2024]. Available at: https://doi.org/10.1016/j.scitotenv.2021.150550

Quintana, C. G.; Olea, P. M.; Abdallah, P. R.; Quintana, A. C. Port environmental management: Innovations in a Brazilian public port. *RAI Revista de Administração e Inovação*. October–December 2016, vol 13, no. 4, p. 261-273. [Accessed: May, 2024]. Available at: https://doi.org/10.1016/j.rai.2016.09.001

Rodrigues, J. C. O índice de desempenho ambiental dos portos brasileiros: panorama e análise crítica. *Terceiro incluído* [online]. NUPEAT, IESA, UFG, 2014, vol.4., no.1, p. 44-65. [Accessed: May, 2024]. ISSN 2237-079X , Available at: https://doi.org/10.5216/teri.v4i1.33943

Silva, O. R.; Meireles, M.; Sanches, C. Gestão ambiental portuária: O problema da poluição atmosféricas no Porto de Santos. ANPAD, 2005, [Accessed: August, 2022]. Available at: http://www.anpad.org.br/diversos/down_zips/9/enanpad2005-apsc-2522.pdf.

Široka, M.; Piličić, S.; Milošević, T.; Lacalle, I.; Traven, L. A novel approach for assessing the ports' environmental impacts in real time – The IoT based port environmental index. *Ecological Indicators*.

[online] 2021, vol. 120, 106949, [Accessed: May, 2024]. Available at: https://doi.org/10.1016/j.ecolind.2020.106949

Souza, F.; Yang, D.; Moreira, A.; Barreto, L.; Pitombo, C. Assessment of container terminals competitiveness in the Brazilian market: a cluster analysis. *Maritime Policy & Management* [online]. 2022, vol. 50, no. 8, p. 1147-1165, [Accessed: May, 2024]. Available at: https://doi.org/10.1080/03088839.2022.2093417

Tichavska, M.; Tovar, B. Port-city exhaust emission model: An application to cruise and ferry operations in Las Palmas Port. *Transportation Research Part A: Policy and Practice*. [online] 2015, vol. *78*, p. 347–360. [Accessed: May, 2024]. Available at: https://doi.org/10.1016/j.tra.2015.05.021

Vilani, R. M.; Cruz, J. L. V.; Pedlowski, M. A. Salty Port: Environmental conflicts resulting from the Açu Port. Rio de Janeiro state. Brazil. *Ambiente & Sociedade* [online]. São Paulo. 2012, vol. 24, no. 1, [Accessed: May, 2024]. Available at: https://doi.org/10.1590/1809-4422asoc20200190r1vu2021L5AO