REVISTA DE GESTÃO E SECRETARIADO
MANAGEMENT AND ADMINISTRATIVE PROFESSIONAL REVIEW
ISSN: 2178-9010

Revista GeSec
São Paulo, SP, Brasil v. 14, n. 8, p. 12674-12693,2023

DOI: http://doi.org/10.7769/gesec.v14i8.2558

Port sustainability initiatives: a study of brazilian public ports

Iniciativas de sustentabilidade portuária: um estudo dos portos públicos brasileiros

Darliane Ribeiro Cunha[1]
Newton Narciso Pereira[2]
José Mariano Moneva[3]

Abstract

The paper aims to identify the environmental sustainability initiatives applied in Brazilian public ports. The survey was conducted with twenty port managers located along the Brazilian coast, and the results revealed that sustainability initiatives in Brazilian public ports are consistent with international practices. The study observed a trend in which ports integrate management indicators with sustainable development goals. Brazilian ports have demonstrated a commitment to publishing sustainability reports, although only eight ports currently use the GRI guidelines to prepare these reports. Therefore, there is room for improvement in aligning with international standards and improving external communication. Companies and stakeholders can compare sustainability reports more easily using a common international standard, facilitating benchmarking and identifying best practices. The enhancement of port resilience to the impacts of climate change requires continuous monitoring, and ports have access to various databases and tools for this purpose. According to the study, the most commonly used databases by the surveyed ports are

[1] PhD in Accounting and Finance from Universidad de Zaragoza, Universidade Federal de Maranhão (UFMA), Av. dos Portugueses, 1966, Vila Bacanga, São Luís - MA, CEP: 65080-805. E-mail: darlianerc@gmail.com Orcid: https://orcid.org/0000-0003-2548-1237
[2] PhD in Naval and Ocean Engineering from Universidade de São Paulo (USP), Universidade Federal Fluminense (UFF), Gragoatá, Niterói - RJ, CEP: 24210-346. E-mail: newtonpereira@id.uff.br Orcid: https://orcid.org/0000-0003-3432-7063
[3] PhD in Accounting and Finance from Universidad de Zaragoza, C. de Pedro Cerbuna, 12, 50009 Zaragoza, Espanha. E-mail: jmmoneva@unizar.es Orcid: https://orcid.org/0000-0003-1619-8042

meteorological/climatological and oceanographic/hydrological. Only 5% of all ports had green tariff incentives to reduce emissions in port regions. Furthermore, nearly 40% of all ports monitored CO2 emissions through emissions inventories, and only two ports employed solar energy. The paper outlines the main environmental sustainability initiatives in Brazilian public ports and provides insights for promoting more sustainable ports and cities.
Keywords: Sustainability. Environment. Climate Change. Renewable Energy. Ports.

Resumo

O trabalho visa identificar as iniciativas de sustentabilidade ambiental aplicadas nos portos públicos brasileiros. A pesquisa foi realizada com 20 gestores portuários localizados ao longo da costa brasileira, e os resultados revelaram que as iniciativas de sustentabilidade nos portos públicos brasileiros são consistentes com as práticas internacionais. O estudo observou uma tendência em que os portos integram indicadores de gestão com objetivos de desenvolvimento sustentável. Os portos brasileiros têm demonstrado um compromisso com a publicação de relatórios de sustentabilidade, embora apenas oito portos atualmente usem as diretrizes GRI para preparar esses relatórios. Por conseguinte, é possível melhorar o alinhamento com as normas internacionais e a comunicação externa. As empresas e as partes interessadas podem comparar mais facilmente os relatórios de sustentabilidade utilizando uma norma internacional comum, facilitando a avaliação comparativa e identificando as melhores práticas. O reforço da resiliência dos portos aos impactos das alterações climáticas exige um acompanhamento contínuo, e os portos têm acesso a várias bases de dados e ferramentas para esse efeito. Segundo o estudo, as bases de dados mais utilizadas pelos portos inquiridos são as meteorológicas/climatológicas e oceanográficas/hidrológicas. Apenas 5% de todos os portos tinham incentivos tarifários ecológicos para reduzir as emissões nas regiões portuárias. Além disso, cerca de 40 % de todos os portos monitorizaram as emissões de CO2 através de inventários de emissões, e apenas dois portos utilizaram energia solar. O documento descreve as principais iniciativas de sustentabilidade ambiental em portos públicos brasileiros e fornece insights para a promoção de portos e cidades mais sustentáveis.
Palavras-chave: Sustentabilidade. Meio Ambiente. Mudanças Climáticas. Energias Renováveis. Portos.

Introduction

Port operations are critical for the economic growth of a region, given that maritime transport accounts for approximately 90% of global trade volume (IMO, 2015), with ports serving as crucial stakeholders in cargo shipping processes. In Brazil, the volume of goods transported by sea in 2020 amounted to approximately 1.151 billion tons, representing a growth rate of 27% compared to 2012, when it stood at 904 million tons (ANTAQ, 2020).

Ports are integral nodes in logistics chains and occupy a pivotal position in the global economy, linking various parts of the world through international transportation. Functioning as logistical nodes, ports are crucial in managing and coordinating material and information flows and serve as interfaces between other nodes within a supply network (Carbone & Martino, 2003; Pereira, 2020).

Ports have traditionally played a pivotal role in promoting economic development in the adjacent cities, enabling market integrations and service agglomerations that generate significant economic and social benefits, as ports have the potential to enhance inland development in several regions within their sphere of influence (Pereira, 2020). When ports increase their regional area of influence, they also generate numerous services and supply chains. Ports can influence cities by attracting specific transport service companies (Zhao et al., 2017).

Ports are vital for both local and global economies. By contrast, ports can cause social and environmental impacts given increased ship flows and operations. From an ecological standpoint, ports can cause considerable consequences and must therefore obtain environmental licenses (Pereira, 2020). Given their particular characteristics, ports constitute very complex systems resulting in various environmental issues, e.g., air and soil pollution, waste generation, and noise (Darbra et al., 2005).

Sustainability initiatives seek to strengthen links between social, natural, and financial capital via improved water use and energy efficiency, reduced greenhouse gas emissions (GHG), reduced waste, increased resilience to climate change, minimised impacts on biodiversity, natural resources and greater social inclusion. Although sustainability is vital for most ports, it has yet to fully integrate into their strategic decision-making processes and operations (Ashrafi et al., 2019).

The demand for a low-carbon economy from stakeholders and the community has compelled ports to undertake sustainability initiatives (ESPO, 2020). While certain industries have been planned and implemented, several initiatives remain that have not yet been

reported, either due to being in the developmental phase or because port authorities do not deem them necessary to disclose to stakeholders. Thus, research involving the consultation of port managers is crucial in identifying potential sustainability practices that may already be present within the port sector.

Ports have a pivotal role to play in addressing climate change on various fronts, with two specific aspects warranting particular attention. Firstly, they contribute to global greenhouse gas (GHG) emissions through their maritime transport operations. Secondly, as crucial global interconnection points that are susceptible to extreme heat events and sea-level rise, they must minimize their emissions and strengthen their resilience to prevent disruption to global supply chains (Cavalli et al., 2021).

Sustainability initiatives implemented in the port sector have not been extensively covered in the literature, except for some ports in North America, Europe, and the Far East of Asia. Consequently, researching the sustainability of ports in developing countries is a crucial area of investigation (Alamoush et al., 2021).

Several studies in the academic literature address sustainability initiatives in ports (Puig et al., 2022; Hossain et al., 2021; Hossain et al., 2019). However, few studies conducted field research with the ports' managers or stakeholders (Michalska-Szajer et al., 2021; Azarkamand et al., 2020; Schrobback & Meath, 2020; Ashrafi et al., 2019; Oh et al., 2018). In general, studies perform content analysis on published sustainability on websites. Furthermore, the majority of studies in this field concentrate on ports in North America and Europe.

Puig et al. (2022) conducted a study to assess the environmental performance of European ports using data collected from a representative sample of EcoPorts members. The researchers utilised the Self-Diagnosis Method to extract information from 97 ports across 18 European maritime countries. The study found that most ports had environmental policies (96%) and conducted inventories of significant environmental aspects (92%). Transparency was also crucial for ports, with 91% communicating their environmental policy to stakeholders and 86% making it publicly available on their websites.

Hossain et al. (2021) conducted a study analysing sustainability initiatives adopted by 36 ports across North America, Europe, and the Asia-Pacific. The researchers collected data and information from port websites and secondary sources. The study found that European ports were more successful in adopting various sustainability initiatives than ports in North America and the Asia-Pacific. The most widely adopted initiatives included a greater emphasis on internal environmental policies and management (including third-party

certifications), investment in proactive environmental solutions, and increased stakeholder engagement.

Sustainability initiatives and environmental performance were also the focus of a study on eighteen Canadian ports. The researchers used twenty-five pre-defined indicators to identify operational trends related to port sustainability. The study considered the information published on the websites of the ports. All major Canadian ports participate in the Green Port program, but only seven have proactively integrated sustainability into their practical operations. Sustainability initiatives include environmental policy developments, environmental monitoring, proactive energy management, stakeholder engagement, sustainability for port users, enhanced environmental reporting, and ongoing research and development (Hossain et al.,2019).

The study by Michalska-Szajer et al. (2021) analysed the sustainability initiatives of six seaports operating in European Union countries. Standardised interviews were conducted with representatives of port authorities via email. Based on the results presented in the study of the paper, it was possible to verify that the authorities of the Polish ports implement initiatives in all three areas of sustainability.

Azarkamand et al. (2020) examined the significance of climate change in ports by conducting a survey at the Greenport Congress with 55 port professionals and environmental experts. The results of the survey showed that Climate Change ranks sixth among the top ten port environmental priorities, while the Carbon Footprint ranks eighth. This highlights the importance of these two issues in the overall set of environmental priorities. Participants emphasized the need for a joint port sector Carbon Footprint scheme that would benefit individual port authorities and the port sector as a whole.

The research conducted by Schrobback and Meath (2020) investigated the sustainability approaches of ports in Australia and New Zealand through an online survey involving thirteen stakeholders related to the port industry. The findings indicate that the sector has begun to develop and execute sustainability strategies, which is evidenced by the high level of implementation of good governance practices, environmental and health measures, safety management practices, and indicators to track sustainability performance. Although the industry has made significant strides in adopting sound general and environmental governance practices, there is still a need to enhance stakeholder awareness and engagement, including disclosure of sustainability performance.

Ashrafi et al. (2019) investigated sustainability strategies and practices in ports, as well as the main motivations and challenges affecting the adoption and implementation of such

practices. The study utilized a questionnaire administered to fourteen port managers from Canadian and US maritime ports. The results indicated that the majority of ports view sustainability as crucial and have implemented various sustainability strategies and practices, including sustainability awareness and training programs, sustainability reporting, and participation in sustainability initiatives and standards such as Green Marine and ISO 14001.

The study by Oh et al. (2018) aimed to identify the key criteria for assessing the sustainability of South Korean ports. The assessment criteria covered all three dimensions of sustainability. A survey was carried out among thirty port managers. The results revealed that the economic aspect of providing employment opportunities was considered the most critical criterion, followed by environmental issues and social factors.

In this context, by surveying port managers, the paper aims to identify the environmental sustainability initiatives applied in Brazilian public ports. In addition, the study verifies whether some regions of Brazil tend to implement more sustainable actions than others with more significant pressure due to their local or stakeholder characteristics.

Literature Review

2.1 Port Sustainability

The United Nations (UN) introduced the 2030 Agenda, a global proposal comprising 17 Sustainable Development Goals (SDGs), in 2015. The SDGs necessitate worldwide cooperation between governments, businesses, and societal organisations to attain mutual prosperity and sustainability objectives (Khaled et al., 2021).

The primary aim of the 2030 Agenda is to aid organisations in optimising their contribution to the SDGs. Aligning with the SDGs enables a company to demonstrate its dedication to sustainable development. To this end, companies should undertake several steps, such as comprehending the sustainable development goals, determining the pertinent sustainable development goals and aligning them with the existing business indicators, establishing goals that positively impact sustainable development goals, embedding sustainability into the core business, and disclosing corporate sustainability practices (SDG Compass, 2015).

The maritime industry has a relevant role in achieving the SDGs in the three pillars of sustainability. In the social pillar, the industry must support gender equality and empower women through a global program and activities to work in the sector. Issues related to the

health and well-being of employees are a central theme of the shipbuilding industry. The sector should help minimise environmental impacts by reducing pollution related to maritime transport in oceans, ports, and coastal regions regarding environmental issues. Additionally, it should promote the financing, research and development of clean energy technologies for the maritime sector (IMO, 2017).

The maritime industry is critical in contributing to global sustainability as a key stakeholder (Wang et al., 2020). Sustainability must be integrated into the port sector, including initiatives to develop a low-carbon economy (ESPO, 2021).

An Environmental Report from ESPO mentions the top 10 environmental priorities for European ports and highlights that climate change was the second priority for ports in 2021 (table 1). According to the report, collaborative efforts have increasingly been applied as a port, and community stakeholders seeking to develop low-carbon economies (ESPO, 2021).

2017	2019	2021
Air quality	Air quality	Air quality
Energy consumption	Energy consumption	Climate Change
Noise reduction	Climate Change	Energy Efficiency
Water quality	Noise reduction	Noise reduction
Dredging	Relationship with local communities	Relationships with local communities
Port garbage/waste	Ship waste	Water quality
Port development	Port garbage/waste	Ship waste
Relationships with local communities	Port development	Dredging
Ship waste	Dredging	Port development
Climate Change	Water quality	Port garbage/waste

Table 1: Environmental priorities for European ports.
Source: ESPO Environmental Report 2021

Air quality has been an issue addressed in recent years, which directly influences ports. Ports must supply electricity to ships using shore power systems during ship docking to meet these criteria (Krämer & Czermański. 2020). Winkel et al. (2016) estimated that 800,000 tons of CO2 could be reduced in 2020 if all ships docked at European ports used shore power. Furthermore, as of 01/01/2021, ships started using low sulfur content fuel (0.5%) while docking (Jonson et al. 2020). These efforts seek to improve the quality of life for those who live around the ports by reducing emissions.

Climate change can affect operations and ship flows at the port level (Becker et al., 2018). Specific ports have already discussed the relevance of this topic. According to a European Sea Ports Organization (ESPO) study, climate change was included on the priority

list for European ports in 2017 (ESPO, 2021). Climate change can impact port operations and should be involved in port sustainability agendas (Scott et al., 2013).

Maritime transport accounts for 13% of the transport sector's Greenhouse Gases (GHG) emissions. To enhance this sector's environmental performance, port authorities, terminals, and other stakeholders have collaborated to improve their practices (Cloquell-Ballester et al., 2020).

Renewable energy sources, like wind and solar power, have proven to be strategic in helping Brazil expand and diversify its electricity grid. Large-scale wind power systems in Brazil began to be installed in 2009, and hundreds of new wind farms have been installed since then. Large-scale solar photovoltaic energy systems started to be widely employed in 2014, signalling that this technology could grow as much as wind power (Santos et al., 2020).

Brazil has considerable potential for generating wind and solar energy. The Northeast stands out, given its high wind potential and numerous sites with Brazil's highest average wind speeds (Bezerra & Santos, 2017).

2.2 The Brazilian Port Sector and Model of Sustainability Reporting for the Sector

The Brazilian port sector comprises 37 public ports, 19 managed by unions via dock companies, which are part of the Port Authority. The other 18 remaining ports are managed by either States or cities via specific legal legislation (Sousa et al., 2020).

The institutional framework of the Brazilian ports is composed of the National Waterway Transport Agency (ANTAQ) and the Special Secretariat for Ports (SEP). The ANTAQ them the function due to regulating, supervising and inspecting activities related to waterway transport and the use of port and waterway infrastructure. SEP is an agency is responsible for advising on policies and guidelines for the port sector, in addition to developing projects and programs related to port infrastructure.

From an environmental management standpoint, ANTAQ plays a fundamental role in proposing actions for public and private ports in Brazil. One important milestone was the publication of “Green Ports”, which was released by ANTAQ in 2011. Sustainable development is established as a principle whereby wealth must be produced to not deplete or reduce natural resources available for future generations and in a way that serves growing world populations, thereby establishing guidelines for quality development. Ports play a significant role in economic and social development, so ports are afforded a certain degree of “consensual damage” within the sector. Thus, planning and monitoring must be carried out to

ensure that port activities result in the lowest possible interference levels for surrounding areas (ANTAQ, 2011).

According to ANTAQ (2011), six environmental principles govern environmental regulations that ports have adopted, and that must be followed to ensure good practices and productive activities. These are sustainable development, caution, prevention, paying for pollution, cooperation, and publicising records. In 2011, ANTAQ and the Interdisciplinary Center for Transport Studies from the University of Brasília entered into a partnership to create a method for an environmental performance index for port facilities. Thus, the Environmental Performance Index (EPI) was created as an essential tool for controlling port environmental management practices (ANTAQ, 2021; Abrantes & Barrella, 2019).

The EPI is defined by ANTAQ as a number that measures the degree of compliance with environmental policy. The EPI allows for comparisons among management and licensing processes for port facilities and generates port administrator knowledge on the strengths and weaknesses of their ecological activities (ANTAQ, 2021).

The index effectively evaluates environmental management at port facilities according to pre-established parameters. The EPI has been applied using a questionnaire online at the ANTAQ website since 2012. Ports have logins and passwords to access the system. When the questionnaires are completed, ANTAQ evaluates the indicators and returns the evaluation results to the ports. Thirty-eight specific environmental performance indicators for ports are evaluated, classified into four categories, and 14 global indicators (Abrantes & Barrella, 2019).

Santos and Gonçalves (2017) state that the EPI is the first Brazilian environmental index specific to the port sector. Prior international initiatives highly influenced it. After its implementation in 2012, many changes have been made to ports relative to their environmental management practices.

The port evaluation results are published in a semi-annual ranking. Values corresponding to the level of compliance are summed up to organise the ranking. The sums range from 0 to 100, thereby forming the EPI score. It is worth noting that environmental legislation is crucial for this index since environmental legislation indicators constitute 85% of the possible EPI score (Santos & Gonçalves, 2017). The EPI started to be used at private ports after 2017. Before this, it was only used at public ports. The main aspects of the assessments are directly focused on environmental issues. The EPI does not focus on broader sustainability criteria, i.e., the economic, social and environmental triple bottom line.

On the other hand, Brazilian Private Use Terminals (TUP) are already being evaluated in terms of sustainable practices. Five terminals representing 60% of container handling in the country were evaluated considering 29 sustainable practices identified in the international literature, and some practices correlate with the EPI. Five Private Use Terminals employed between 17 and 10 sustainable practices (Calcerano & Hilsdorf, 2021).

ANTAQ's model is focused only on the environmental aspect of sustainability. In this way, Brazilian ports must seek complementary models that consider the other pillars of sustainability. The Global Reporting Initiative (GRI) guidelines have the advantage of already being used by the world maritime sector and are better known by many stakeholders.

Method

This study is an exploratory and descriptive field research paper that uses qualitative analysis of opinions on public port sustainability in Brazil. It is important to highlight that respondents were not identified in the questionnaire, ensuring the respondent's anonymity.

The survey design for initiatives aimed at promoting port sustainability was informed by a literature review, which drew upon works by Puig et al. (2022), Hossain et al. (2021), Michalska-Szajer et al. (2021), Schrobback and Meath (2020), and Ashrafi et al. (2019). The survey questions were framed around themes that considered the Environmental Report from ESPO, which outlined the key environmental priorities for European ports, including air quality, climate change, energy efficiency and other aspects not explored by Environmental Performance Index (EPI).

The questionnaire contained open (write in your answer) and closed (multiple choice) questions. The questionnaire addressed the respondent's profile, reports and indicators (preparation of sustainability report, use of indicators, use of GRI guidelines, linking management indicators with sustainable development goals) and environmental priorities already mentioned.

The study population was thirty-five Brazilian public ports. The *Cachoeira do Sul* and Estrela ports were excluded from the population since they are in the process of changing their port authorities and did not provide data. The study population is detailed in Table 2.

Item	**PORT NAME**	**PORT AUTHORITY (original company names kept in Portuguese)**	**REGION**
1	*Antonina*	*Administração dos Portos de Paranaguá e Antonina*	SOUTH
2	*Paranaguá*	*Administração dos Portos de Paranaguá e Antonina*	SOUTH

3	*Aratu*	*Companhia das Docas do Estado da Bahia*	NORTHEAST
4	*Ilhéus*	*Companhia das Docas do Estado da Bahia*	NORTHEAST
5	*Salvador*	*Companhia das Docas do Estado da Bahia*	NORTHEAST
6	*Areia Branca*	*Companhia das Docas do Rio Grande do Norte*	NORTHEAST
7	*Natal*	*Companhia das Docas do Rio Grande do Norte*	NORTHEAST
8	*Maceió*	*Companhia das Docas do Rio Grande do Norte*	NORTHEAST
9	*Cabedelo*	*Companhia Docas da Paraíba*	NORTHEAST
10	*São Sebastião*	*Companhia Docas de São Sebastião*	SOUTHEAST
11	*Vitória*	*Companhia Docas do Espírito Santo*	SOUTHEAST
12	*Barra do Riacho*	*Companhia Docas do Espírito Santo*	SOUTHEAST
13	*Belém*	*Companhia Docas do Pará*	NORTH
14	*Santarém*	*Companhia Docas do Pará*	NORTH
15	*Vila do Conde*	*Companhia Docas do Pará*	NORTH
16	*Angra dos Reis*	*Companhia Docas do Rio de Janeiro*	SOUTHEAST
17	*Itaguaí*	*Companhia Docas do Rio de Janeiro*	SOUTHEAST
18	*Niterói*	*Companhia Docas do Rio de Janeiro*	SOUTHEAST
19	*Rio de Janeiro*	*Companhia Docas do Rio de Janeiro*	SOUTHEAST
20	*Forno*	*Companhia Municipal de Administração Portuária*	SOUTHEAST
21	*Santos*	*Santos Port Authority*	SOUTHEAST
22	*Santana*	*Companhia Docas de Santana*	NORTH
23	*Fortaleza*	*Companhia Docas do Ceará*	NORTHEAST
24	*Itaqui*	*Empresa Maranhense de Administração Portuária*	NORTHEAST
25	*Manaus*	*Superintendência Estadual de Navegação, Portos e Hidrovias*	NORTH
26	*Recife*	*Porto do Recife*	NORTHEAST
27	*SUAPE*	*Suape*	NORTHEAST
28	*Pelotas*	*Portos RS*	SOUTH
29	*Porto Alegre*	*Portos RS*	SOUTH
30	*Rio Grande*	*Portos RS*	SOUTH
31	*Imbituba*	*SCPAR*	SOUTH
32	*São Francisco do Sul*	*SCPAR*	SOUTH
33	*Laguna*	*SCPAR*	SOUTH
34	*Porto Velho*	*Sociedade de Portos e Hidrovias do Estado de Rondônia*	NORTH
35	*Itajaí*	*Superintendência do Porto de Itajaí*	SOUTH

Table 2: Population
Source: Own elaboration (2022).

The questionnaire was disseminated using Google. The requests and link for the questionnaire were sent to all public ports in Table 2 via email, via ports' websites on their official communication channels, via a specific federal government platform for accessing information (ombudsman services for access to information) and/or via specific state government platforms.

The answers were obtained from June 5th to December 3rd, 2021. The study resulted in a sample of twenty ports (57% of the total), as some questionnaires were answered by the port authority. The port authority's responses were for all ports under its management.

Regarding data treatment, the open questions were grouped by type of response, considering response similarity. The answers to the closed questions were directly quantified using a data collection instrument without data analysis software.

Results and Discussion

More than half of all Brazilian public ports participated in this survey. Our study included 20 ports representing a variety of port profiles in terms of size, geographic location, and commercial profile. Of the ports in the study, 40% were located in the southeast, 35% in the northeast, 15% in the north, and 10% in the south.

The Southeast concentrates a large share of Brazilian foreign trade. It is essential to highlight that in 2020, 45.5% of all cargo handled by Brazilian ports was carried out in the Southeast, 28.8% in the Northeast, 14.3% in the South, 11.1% in the North, and 0.3% in the central-west.

All respondents were linked with sustainability or environmental departments. The surveyed managers had different degrees. 33% had Engineering degrees, 25% had Applied Social Science degrees, 17% had Biological Science degrees, 17% had Hard Science and Earth Science degrees, and 8% had degrees in other areas.

We identified the sustainability initiatives present at Brazilian public ports. Most respondents (95%) said they publish an annual sustainability report and use sustainability indicators. 42% of the respondents use the Global Reporting Initiative (GRI) guidelines to publish their sustainability reports. 42% of the respondents use the ANTAQ model, 5% of the respondents use their model, and 11% use other models. Of the eight ports that use the GRI guidelines, seven are located in the Southeast, and one is in the Northeast.

A growing number of companies publish sustainability reports in the private sector, especially among large companies. KPMG highlights that 96% of the 250 largest companies in the world, according to Forbes, have published Corporate Social Responsibility (CSR) information using sustainability reports, while most use international models. The GRI remains the dominant global standard for sustainability reporting (KPMG, 2020). The GRI model is a voluntary proposal that includes indicators classified under three sustainability pillars (economic, social, and environmental), and includes governance in the latest version.

The ANTAQ model only focuses on environmental aspects, despite being widely accepted among Brazilian ports, as was previously mentioned, and all ports use this model as an institutional parameter. However, the results show that 42% use this model only to prepare the sustainability reports.

There is a new tendency to link traditional sustainable development goals (SDGs) with management goals. Most Brazilian ports surveyed (95%) stated that they have management indicators linked to sustainable development goals.

It is vital that companies include SDGs in their reporting and management to show that the company is aware of how these contribute to global problems. The KPMG study highlights that 69% of all companies used SDGs in their sustainability reports in 2020, up from 39% in 2017. This increase may be due to more significant pressure from company stakeholders. It is also likely that more companies will better understand SDGs and feel more comfortable using them in their sustainability reports (KPMG, 2020).

By contrast, ANTAQ developed a study to assess the impacts and risks of climate change among Brazilian public ports. The results showed relevant risks for more than half of the 37 ports along the Brazilian coastline.

It is extremely important to study the ability of ports to deal with climate change effects. Only 30% of the surveyed ports stated that they faced operational challenges related to climate change (e.g., more frequent storms, floods, wind or wave conditions). Few ports (35%) had taken measures to adapt existing infrastructure to projected climate change effects.

Approximately 45% thought that climate change impact could be dealt with via new infrastructure development projects. Regarding this, the results show that ports concerned with climate change impacts and changes to new infrastructure projects were located in the north (33%), northeast (22%), southeast (22%), and south (22%). This suggests that ports located in the North and Northeast see a greater need to consider climate change impacts since they are already feeling these effects in their daily operations. For example, changes in rainfall patterns in the north and northeast directly impact grain and vegetable shipping. Furthermore, some ports are located in regions subject to impacts from rising sea levels, which could lead to erosion and increased current speeds (Neves & Muehe, 1995; Rodríguez et al., 2016; Alfredini et al., 2021).

The ESPO study (2021) shows that European ports are more concerned with climate change since 53% stated that their ports were facing operational challenges related to climate change, while 65% were taking measures to adapt existing infrastructure to climate changes, and 78% of all European ports surveyed said that climate change impacts would be accounted for in new infrastructure development projects.

Ports must increase their resilience to climate change impacts, and specific monitoring must constantly be undertaken. In the study, we observed that most Brazilian ports surveyed used two specific databases for monitoring port areas. Meteorological/climatological databases are used by 80% of all respondents, while oceanographic/hydrological databases are used by 70% of all respondents distributed along the Brazilian coastline. These data are essential for monitoring climate change impacts since they can serve as instruments for

monitoring rising sea levels, wind speed, and precipitation, the most prominent impacts affecting Brazilian ports. These impacts affect ports along the coastal zone, increasing risks to their operations (Izaguirre et al., 2021).

Sustainability aspects should also consider possible port incentives (Sköld, 2019). Green incentives, like different tariffs applied to sustainable cargo or ships already being used by major international ports, could be implemented as incentives. According to ESPO (2021), 55% of all European ports surveyed used differing tariff systems. Only 5% had differentiated tariff systems compared to the ports evaluated here. European ports have the highest incentive rates. However, both North America and Asia are currently developing differentiated tariff rates and incentive structures (Sköld, 2019). Most incentives offered by ports to shipowners are related to reducing carbon emissions from ships when they arrive at the port.

Greenhouse Gas (GHG) emission inventories are needed to move towards low-carbon economies. This inventory would allow ports to identify the main sources of GHG emissions in processes and activities (Yang et al., 2021). 40% of the surveyed ports prepared GHG emission inventories, 40% are in the process of creating these inventories, and 20% still need an inventory system in place.

Ship emissions while in port are of increasing concern, especially with respect to SOx, NOx and PM emissions that affect the health of local populations (Aregall et al., 2018).

Most surveyed ports (70%) performed some air quality monitoring. The respondents stated that they monitored for black smoke emissions. Regarding monitoring frequency, only two ports stated that they carry out monthly monitoring. In contrast, three carry out quarterly monitoring, two carry out bi-annual monitoring, and the other ports still need to declare the frequency with which they perform monitoring. The ports that do carry out monitoring are located in the Southeast (43%), the North (21%), the Northeast (21%), and the South (14%).

No port performed integrated air quality monitoring in conjunction with other companies within the port systems. However, the respondents thought this was an essential issue since 40% of all surveyed ports are implementing monitoring systems throughout the port complex.

One alternative to monitoring air quality at ports is using a mathematical model built from data from the Automated Identification System (AIS), combined with ship emission factors, to estimate emissions for the entire port area (Yang et al., 2021).

Although the Environmental Performance Index (EPI) has criteria for evaluating shore power at ports, no Brazilian public port has received a score for this criterion since these

supply systems are yet to be available for ships in Brazil. GHG emissions are one of the main impacts related to climate change.

Given the importance of gas emissions in helping reduce pollution, ports were asked how they supply and use renewable energy to ships. According to our results, Brazilian public ports do not currently prioritise renewable energies. Only two ports have solar energy facilities, and these ports are located in the Northeast. In contrast, one port has a hydroelectric power facility, and this port is located in the Southeast. One port in the South stated that it is installing solar panels to provide lighting/energy to administrative departments. Most surveyed ports did not use renewable energy or used less than 20% renewable energy for their operations. Only one port used more than 80% renewable energy.

The ports are interested in projects related to implementing renewable energy systems in the coming years. In short to medium term, 65% of surveyed ports are interested in implementing solar energy systems, 54% are located in the Southeast, 38% in the Northeast, and only 8% in the South. These findings correlate with the Brazilian Atlas of Solar Energy (2017), according to Pereira et al. (2017). Regarding wind energy, we observed that 45% of all ports are interested in installing wind energy facilities in the medium term. 56% of these were located in the Southeast, and 44% in the Northeast, which have favourable conditions for using wind power, according to Amarante et al. (2010).

Conclusion

The disclosure of environmental sustainability initiatives in Brazilian public ports appears to align with international practices, as suggested by the study results. The study observed a trend in which ports integrate management indicators with sustainable development goals.

Brazilian ports have demonstrated a commitment to publishing sustainability reports, although only eight ports currently use the GRI guidelines to prepare these reports. Therefore, there is room for improvement in aligning with international standards and improving external communication. Companies and stakeholders can compare sustainability reports more easily using a common international standard, facilitating benchmarking and identifying best practices.

The results indicate that only 30% of the surveyed ports reported facing operational challenges related to climate change. Of these, 35% had taken measures to adapt existing infrastructure to projected climate change effects, and approximately 45% believed that the

impacts of climate change could be addressed through new infrastructure development projects.

The enhancement of port resilience to the impacts of climate change requires continuous monitoring, and ports have access to various databases and tools for this purpose. According to the study, the most commonly used databases by the surveyed ports are meteorological/climatological and oceanographic/hydrological.

Despite growing concerns about the environmental impacts of ports and their ability to withstand the effects of climate change, the implementation of tariff incentives to attract environmentally-friendly ships to docking facilities is still limited, with only 5% of all ports having such a system in place. However, around 40% of the ports surveyed have taken steps to monitor CO2 emissions by adopting emission inventories. Furthermore, 70% of ports perform some type of air quality monitoring, with the majority of monitoring taking place in the Southeast region of Brazil.

While few Brazilian ports have currently implemented renewable energy systems, only two using solar energy, many have expressed plans to expand their use of solar and wind energy. The study shows that 65% of surveyed ports are interested in implementing solar energy systems in short to medium term, with 54% located in the Southeast, 38% in the Northeast, and only 8% in the South.

The ports in areas with favourable characteristics for solar and wind energy generation along the Brazilian coastline are more likely to take advantage of these energy resources. However, it could be improved by providing more specific information about the areas where these ports are located, such as their names or geographic coordinates. Additionally, it could be helpful to provide more details about the characteristics that make these areas favourable for alternative energy generation.

The study is limited to the Brazilian public port sector, and we recommend applying this study to other ports or port terminals. In addition, it would also be interesting to identify the perception of stakeholders on sustainability initiatives in the port sector.

The study analyses the sustainability practices applied in the Brazilian port sector. In addition to inspiring ports to include sustainability initiatives, it also assists in transparency and accountability to the most diverse stakeholders. Based on the findings, we recommend managers promote dialogues with stakeholders to help build more sustainable ports and cities.

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Submetido em: 03.07.2023

Aceito em: 03.08.2023