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Calcerano, Tomaz Alexandre; Hilsdorf, Wilson de Castro
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Sustainability practices in container terminals in Brazil

Tomaz Alexandre Calcerano^a, Wilson de Castro Hilsdorf^{a*} 

^aCentro Universitário da FEI, São Bernardo do Campo, SP, Brasil

*wicastro@fei.edu.br

Abstract

Paper aims: This paper aims to investigate which sustainability practices are being applied in port terminals in Brazil and to identify the driving forces and obstacles to the implementation of these practices.

Originality: The research contributes to fill gaps that still remain in the literature, such as the need to identify and analyze sustainability requirements in the port industry in a more tangible way, bringing new evidence to a better understanding of how the port industry perceives and addresses sustainability issues.

Research method: The paper presents an in-depth multiple case study in the five largest terminals in Brazil, which correspond to approximately 60% of the Brazilian handling of containers.

Main findings: The results present evidence of the evolution of the commitment to environmental preservation and the progressive dissemination of sustainability practices. The main difficulties are the high costs and lack of support from the port authority to encourage the implementation of some practices.

Implications for theory and practice: This study aimed to disclose sustainability practices adopted at container terminals in Brazil, as well as provide some content, both for academia and companies, that may assist in developing new research on this theme and implementing these practices in other organizations.

Keywords

Ports industry. Maritime transport. Sustainability.

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1. Introduction

Maritime transport and ports are essential components of international trade. Maritime transport represents one of the largest and most complex control and regulation operations of water and air pollution sources in the world, and ports are important economic, industrial and logistics centers, which also contribute significantly to the pollution of coastal urban zones (Sislian et al., 2016). Container terminals play an important role in the global supply chain and provide an interface between maritime and land transport (Lu et al., 2016b). The global handling of container terminals grew by 137% from 2008 to 2017, reaching approximately 700 million TEUs (*twenty-foot equivalent units*) due to the development of international trade (International Association of Ports and Harbors, 2016). The growth in container capacity has also raised concerns about the environmental impact that these operations may cause, including noise, air pollution, residues and energy demand. Therefore, container terminal operators have started setting wider sustainability policies that go beyond environmental management and focus on understanding the relations among economy, society, environment and fair distribution of resources and opportunities (Lu et al., 2016b).

In Brazil, the port industry (organized ports and private use terminals) handled 10.5 million TEUs in 2019 (Agência Nacional de Transportes Aquaviários, 2017). The low costs of ship transport and the long coast in Brazil provide the ideal scenario for the development of the port industry in the country. According to the Bureau of Ports (Brasil, 2014), environmental management schemes have been implemented that aim at



modernizing the industry based on sustainability principles and with a focus on the public interest. The SEP follows and coordinates environmental licensing procedures for the areas of public ports, private use terminals, and land and maritime access works (Brasil, 2014).

However, according to Galpin et al. (2015), it is possible to observe gaps between the principles and sustainable models discussed in theory and the organizational policies applied in practice. The measurement of sustainable development in activities and/or port areas is a theme that has not been thoroughly studied thus far. According to Di Vaio & Varriale (2018), the literature still lacks further studies to identify and analyze the sustainability requirements in the port industry in a more tangible way. For Ashrafi et al. (2019), it is important to carry out more case studies to analyze how ports realize and approach sustainability. Schrobback & Meath (2020) claim that the existing literature on sustainability in the port context provides a limited view of how the theme is dealt with on a corporate level. In addition, Zheng et al. (2020), in a recent study on research trends on port sustainability, emphasize the importance of new qualitative studies on the topic and suggest expanding the scope of this research to other regions of the world such as Asia, Africa and South America.

In this context, this study aimed to identify which sustainability practices have been implemented by container terminals in Brazil and the driving forces and obstacles to the implementation of these practices.

This study was divided into six sections as follows. Section 1 presents the introduction of this study and its objectives. Section 2 presents the theoretical background that supports this study. References are presented regarding the environmental and sustainability practices in seaports and port terminals. Section 3 presents the methodology used. Section 4 shows the data obtained in the field study, while section 5 analyzes and discusses these data. Section 6 describes the conclusions obtained and presents suggestions for future research on the theme.

2. Sustainability

2.1. Sustainability practices in ports

The sustainability principles emerged in a social-historical context of environmental abuses, considering a general social awakening regarding issues that involve the relation with the planet. As ports are organizations that play an important role in integrating supply chain operations, they need to adopt sustainability requirements in their operations, which has received considerable recognition. Lu et al. (2016a) defined port sustainability as the “company strategies and activities that meet the current and future needs of the port and its interested parties, while protecting and sustaining human and natural resources”.

A proposal to apply environment management systems in specific ports, as well as a system of port sustainability indicators, was carried out by Peris-Mora et al. (2005) at the Port of Valencia as a part of the Ecoport project, using a multicriteria methodology that could be expanded to European ports. Puig et al. (2015) analyzed the environmental priorities of 79 European ports according to their characteristics based on European Sea Ports Organisation (ESPO) reports and a preliminary selection of environmental performance indicators. Schrobback & Meath (2020) also suggest the definition of objectives and targets for environmental management practices.

These contributions clearly identify with the classical view of sustainability and the environment. While the number of proposals is already limited, proposals that introduce suitable elements and dimensions to the concept of sustainable development are even scarcer. After including and analyzing the economic aspects in the reports on sustainability in Spanish ports, Asgari et al. (2015) applied the analytical hierarchy process (AHP) to the ports in Great Britain to establish a ranking of these ports based on economic and environmental aspects. Finally, Shiau & Chuang (2015), using the procedure of the social construction of technology (SCOT), were able to identify sustainable development indicators for the Port of Keelung regarding environmental, economic and social dimensions.

Throughout the years, the focus on port sustainability has become increasingly important on a global scale. Gupta et al. (2005) discussed the Environmental Management Plan (EMP) using a variety of methods to protect the environment, as well as prevent and control pollution during the construction and operation of a large terminal.

Saengsupavanich et al. (2009) proposed the *12 Environmental Performance Indicators* (EPIs) to evaluate industrial ports. Peris-Mora et al. (2005) proposed an *Environmental Indicator System* (EIS) according to different levels of managerial decisions. In addition to the economic aspect, the authors focused on the environmental indicators.

According to Dinwoodie et al. (2012), ports have adopted a mix of awareness training and rigid regulation to fill the gap between environmental aspirations and practices. The Council Directive CE85/337 of the European Union (later altered to EC97/11) recommended ports to perform an environmental audit, covering handling and storage areas for prescribed materials, waste emissions, waste disposal areas, fishing, wetlands and specific

zones of scientific and cultural interest, compliance with conventions and codes related to sea pollution and hazardous goods and prioritizing environmental protection issues. Audits are not mandatory; however, port managers are responsible for environmental damage, with subsequent punitive damages. Di Vaio & Varriale (2018) evidenced that environmental regulations should also provide guidelines for monitoring and measure the effects of environmental choices.

Organizational actions, such as investment in equipment to mitigate pollution, usually reflect managers' decisions, which are sustained by an underlying sustainability strategy. Nevertheless, the development of environmental awareness in ports and input-output modeling based on process systems of environmental port management are still little explored. According to Dinwoodie et al. (2012), few ports in Europe have effective management, with 32% planning to outsource environmental management activities and 22% hiring specialists.

2.1.1. Sustainability practices in container terminals

A research project in the academic literature on container terminals reveals only a few studies on sustainable container terminals. Sisson (2006) and Pedrick (2006) presented definitions of sustainable container terminals and drew attention to their characteristics. Lazic (2006) and Clarke (2006) suggested that automated equipment and semiautomated cargo handling may be elements of a sustainable container terminal. A series of articles address topics related to a general description of sustainable ports without providing any empirical analysis (Yang, 2015).

While previous studies addressed several research topics on the environmental aspects in sustainable ports, few studies focused on these issues in container terminals. In Europe, the Environmental Code of Practice for ports in the EU was established in 1994 and updated in 2003. In 2000, the port authority of Valencia was the first to try to implement a system of environmental port management, developed within the EcoPort project (2013), in which the self-diagnosis method (SDM) and the Port Environmental Review System (PERS) were established (Yang, 2015).

According to Davarzani et al. (2016), ports started to encourage ships to turn off their engines and generators while docked and to connect to an onshore power supply, a process called "cold ironing". The same practice was suggested by Schrobback & Meath (2020).

For multimodality and sustainability, the Port of Gothenburg works as a model because half of the container volume is transported to the countryside through an extensive domestic railway network that extends to Norway (Notteboom, 2013). In addition, the Port of Gothenburg was the first port in the world to offer high-tension onshore power supply (OPS) for cargo ships in 2000. OPS replaces the onboard power supply generated by auxiliary diesel engines with power generated onshore, resulting in a significant reduction in greenhouse gas emissions in the port industry (Hakam & Solvang, 2013).

According to Hakam & Solvang (2013), the Port of Oslo in Norway released the Oslofjord Clean Up project in 2000 to remove contaminated sediments deposited on the bottom of the canal over a century of industrial activity.

Baumgartner et al. (2008) developed a qualitative research project to investigate how computerized systems for routing and scheduling of trucks that arrive at the port have a positive impact on CO₂ emissions.

Ashrafi et al. (2019) rated ports that monitor and control their sustainability practices using ISO standards and found that 65% of them adopt some of these practices, such as performance indicators, green certifications, and sustainability reports.

In the US, the California Air Resources Board (CARB) had a great impact on most sustainable initiatives implemented in the main container ports of Los Angeles, Long Beach and Oakland. An important rule imposed on the ships by the CARB program in 2008 is that, within 40 nautical miles from the Californian coast, marine fuels with a low sulfur concentration must be used instead of fuel oil (Cannon, 2008). For the docked ships, it was mandatory to reduce the emissions of nitrogen dioxide and particles by 10% in 2010, while it is expected that they meet the demand to reduce such emissions by 80% by 2020 (Cannon, 2008). For container ships, the change towards natural gas seems to become a common decision. In 2013, there were over 50 ships ready or on request, powered by natural gas across the world (Hakam & Solvang, 2013).

According to Hakam & Solvang (2013), the practices of five container ports in Asia and America present similarities and differences among their policies, concepts and environmental management measures. The research results revealed that Shenzhen (China) and Hong Kong were reducing the emissions related to ships and ports to become sustainable ports, and the authors suggested that sustainable ports should encourage stronger cross-border collaboration.

DP World – the terminal operator based in Dubai – successfully implemented the replacement of diesel engines with electric engines in rubber-tyred gantry (RTG) cranes, thus reducing the monthly diesel consumption

by approximately 109,000 liters (Haine, 2009). According to Vujičić et al. (2013), the environmental impacts between conventional and electric RTG cranes differ by approximately 2.5%.

Yang (2015) developed a classification of sustainability practices by port terminal operation, which includes berth areas, yard areas, gates areas for transport vehicles, and integration practices among terminal areas. This classification was obtained by means of interviews with the terminal managers, who ranked the level of importance of each practice within its area of operation. Based on the areas of operation defined by Yang (2015), the sustainability practices in port terminals identified in the literature are consolidated in Table 1.

Table 1. Consolidation of sustainability practices in port terminals identified in the literature.

Terminal Area	Practices	Authors
Berth Area	Deployment of on-shore power supplies	Yang (2015), Davarzani et al. (2016), Schrobback & Meath (2020)
	Layout of automatic mooring system	Yang (2015)
	Gantry cranes with twin-lift or tandem-lift operating capabilities	Yang (2015)
	Shortened moving distance of tractor-trailers or handling equipment in the CT	Yang (2015)
	Optimal CT layout for energy conservation and carbon reduction	Yang (2015)
	Reduction in speed of ships near the port	Yang (2015), Hakam & Solvang (2013)
	Incentives for ships with gas emission reduction plan	Hakam & Solvang (2013), Yang (2015), Cannon (2008)
	Transformation of contaminated dredging sediments into other substances	Hakam & Solvang, (2013)
Yard Area	Use of automated handling equipment	Hakam & Solvang (2013), Lazic (2006), Clarke (2006), Yang (2015)
	Conversion of diesel equipment to electric power systems	Hakam & Solvang (2013), Lazic (2006), Clarke (2006), Vujičić et al. (2013), Yang (2015)
	Replacement of old equipment or acquisition of electric-powered equipment	Hakam & Solvang (2013), Yang (2015)
	Installation of wireless remote control systems or laser sensor technology in operating system	Yang (2015)
	Adoption of measures to reduce tractor-trailer engine idling	Hakam & Solvang (2013), Yang (2015)
Gate Area	Temperature control in low energy for containers reefers	Hakam & Solvang (2013)
	Establishment of OCR and RFID systems to speed up the passage of tractor-trailers through the gate area	Yang (2015)
	Installation of a gate assignment system to reduce external trucks' queuing time and gate passage time	Yang (2015), Baumgartner et al. (2008)
	Control of harbour and stevedore operations via electronic data transmissions	Yang (2015)
	Requiring that external vehicles turn off their engines while idling and queuing to enter the gate	Hakam & Solvang (2013), Yang (2015)
	Use of IC tags or smart cards to facilitate passage through control points	Yang (2015)
Integrated Area	Replacement of road modal by rail modal	Hakam & Solvang (2013), Notteboom (2013)
	Use of hybrid and environmentally-friendly vehicles and the use of ultra-low-sulphur fuel oil to reduce air pollution emissions	Yang (2015)
	Restriction on entry into the port area by older vehicles, while encouraging replacement by environmentally-friendly vehicles	Yang (2015)
	Implementation of energy conservation and carbon reduction measures in offices	Yang (2015), Haine (2009)
	Focus on port land, air and water quality, ecological protection, and pollution prevention	Hakam & Solvang (2013), Yang (2015), Ashrafi et al. (2019)
	Establishment of elevated roadways out of the port area	Yang (2015)
	Implementation and monitoring of sustainability KPI's	Peris-Mora et al. (2005), Shiau & Chuang (2015), Saengsupavanich et al. (2009), Sisson (2006), Pedrick (2006), Asgari et al. (2015), Di Vaio & Varriale (2018), Ashrafi et al. (2019), Schrobback & Meath (2020)
	Audits of environmental regulations	Hakam & Solvang (2013), Dinwoodie et al. (2012), Gupta et al. (2005), Lu et al. (2016a), Di Vaio & Varriale (2018), Ashrafi et al. (2019)
	Environmental monitoring around the port	Hakam & Solvang (2013), Puig et al. (2015), Laxe et al. (2016), Schrobback & Meath (2020)
	Generation of energy through friendly systems (wind or biomass)	Davarzani et al. (2016), Schrobback & Meath (2020)

3. Research methods

3.1. Scope

The consolidation of practices presented in Table 1 was used to elaborate the research protocol for the field studies. Container terminals were selected from the three largest Brazilian ports – Port of Santos, Port of Paranaguá, and Port of Itajaí, which correspond to approximately 60% of the Brazilian handling of containers. The first terminal analyzed was BTP (*Brasil Terminal Portuário*), located at the Port of Santos. The second terminal was APM Terminals, which originated as an operational branch of the Maersk Line, located at the Port of Itajaí. The third terminal was *Santos Brasil Participações S/A (Santos Brasil)*, a Brazilian container operation and logistics company located at the Port of Santos. The fourth terminal was *Grupo Libra*, one of the largest ports and logistics operators of foreign trade in Brazil. The fifth terminal was TCP (*Terminal de Contêineres de Paranaguá*) located at the Port of Paranaguá.

3.2. Methodology

This research had an exploratory objective, using the method of multiple cases studies in the specific context of container port terminals in Brazil. The replication logic was used in five container terminals in the three largest Brazilian ports, which due to their size and characteristics cause impacts on the social, economic, and environmental dimensions in their respective regions. A principle underlying data collection in case studies is triangularization, that is, the combination and use of different methods to study the same phenomenon. The data regarding practices used by the participating companies were obtained through *in-loco* observations, analysis of documents and records related to sustainability and face-to-face interviews. The interviews were recorded on audio and had an average duration of about one hour with professionals in management positions of the environment and operations areas.

A database was used to store the information generated from the multiple sources of evidence and information, structured in a way to establish a logical link between the various sources of evidence and the various research variables. The data analysis used the content analysis technique and consisted of deepening and examining the data set of all the evidence collected at the five terminals, as proposed in the conceptual model of the study, to obtain an analytical result and identify if the sustainability practices, highlighted by the academic literature, are implemented in these terminals. The amount of information obtained did not justify the use of software for data analysis.

The results are presented in binary form, with YES or NO answers, that is, whether the sustainability practice is implemented or not. This form was adopted to facilitate the analysis and enable the achievement of the proposed objectives and represent the final conclusion of the researchers after evaluating the data obtained from different sources.

4. Results and analysis

This section describes the sustainability practices observed at the terminals under study and analyzes the results obtained, based on the practices presented in Table 1.

This study included five large-scale terminals (*Santos Brasil*, *Libra Terminais Santos*, *Brasil Terminais Portuários - BTP*, *APM Terminals*, and *Terminal de Contêineres de Paranaguá - TCP*), according to the classification adopted by the National Bank for Economic and Social Development (BNDES), while *APM Terminals* is the only multinational company. Although all terminals are considered to be large-scale, the *Santos Brasil* and *BTP* terminals have superior handling (see Figure 1). The reason for this change is that these terminals are located at the Port of Santos, the largest in Latin America, while *TCP* and *APM* are located in ports with lower handling levels.

Analyzing the numbers related to electric power and water consumption from an environmental perspective, it is possible to establish a direct relation between the handling at the terminal and consumption (see Figure 2).

To provide a general view of the results collected, it is possible to observe that Figure 3 presents the adoption of sustainability practices at the terminals by operation area, according to the classification by Yang (2015). The figure shows what was observed in the case studies, revealing that the most adopted practices are those made mandatory by the port authority and/or controlling agencies. These practices are concentrated at the terminals' gate areas, where they concern the way to inspect the cargoes, and at integration among the areas, in which they usually concern follow-up practices and environmental information management demanded by the controlling agencies.

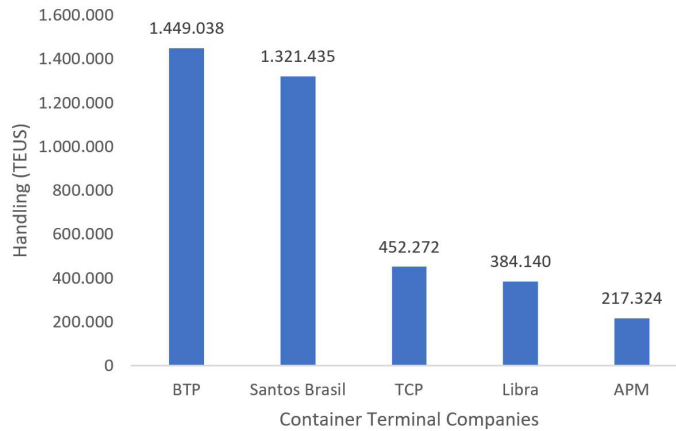


Figure 1. Handling of TEUs at the companies under study. Source: Companies under study.

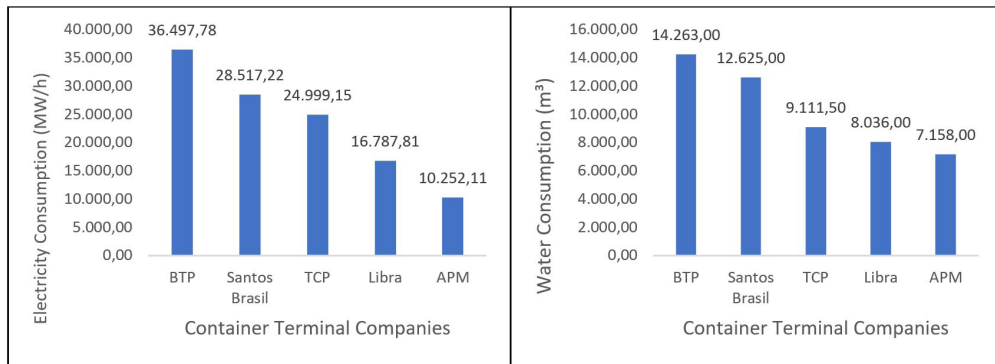


Figure 2. Electric power and water consumption (2017) at the companies under study. Source: Companies under study.

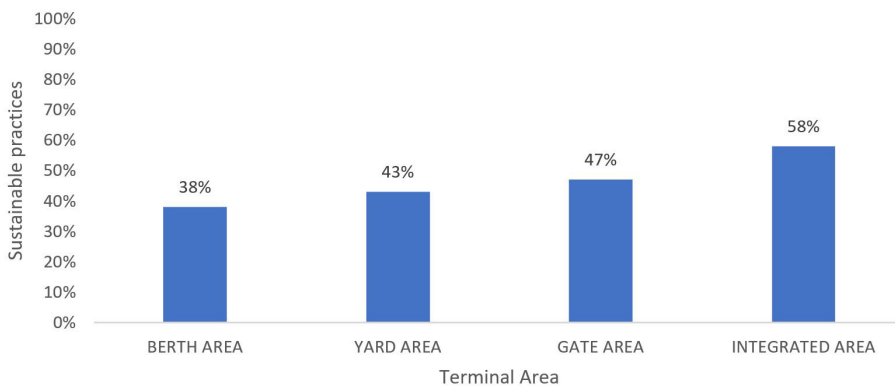


Figure 3. Practices implemented by terminal area – Number of “yes” responses to total responses. Source: Authors.

- Berth Area

The first area of operation defined by Yang (2015) is called the *berth area*, in which all ship loading and unloading takes place. The literature identifies eight practices regarding sustainability in this area.

As shown in Table 2, four practices are not adopted by any of the five Brazilian terminals. Two of them, *deployment of onshore power supplies* and *layout of automatic mooring system*, depend for their implementation on large investments that require incentives from the port authority, which does not happen in the Brazilian scenario. Davarzani et al. (2016) and Schrobback & Meath (2020) describe cases in which the implementation of these practices had incentives from the port authority as in ports in Australia and New Zealand, in contrast

Table 2. Berth area.

BERTH AREA	BTP	Santos Brasil	Libra	APM	TCP
Deployment of on-shore power supplies	No	No	No	No	No
Layout of automatic mooring system	No	No	No	No	No
Gantry cranes with twin-lift or tandem-lift operating capabilities	Yes	Yes	Yes	Yes	Yes
Shortened moving distance of tractor-trailers or handling equipment in the CT	Yes	Yes	No	Yes	Yes
Incentives for ships with gas emission reduction plan	No	No	No	No	No
Transformation of contaminated dredging sediments into other substances	No	No	No	No	No
Optimal CT layout for energy conservation and carbon reduction	Yes	Yes	No	No	No
Reduction in speed of ships near the port	No	Yes	No	Yes	Yes

to the Brazilian case. The other two practices not implemented by any of the terminals, *incentives for ships with gas emission reduction plan* and *transformation of contaminated dredging sediments into other substances*, do not depend on large investments, but on the regulation and coordination of the same port authority, in the Brazilian case controlled by federal government.

The other four practices were observed in most terminals because they presented economic and environmental advantages to the terminals.

Yang (2015) classifies the *gantry cranes with twin-lift or tandem-lift operating capabilities* sustainability practice as the one with the most importance in the berth area. The result shows that this practice is also considered to be especially important in Brazilian terminals, as all of them have equipment that allows this type of operation. However, terminals only use twin-lift gantry cranes as a consolidated practice, different from tandem-lift gantry cranes, which are not used because they require a larger side area and new technologies that are not available in Brazilian terminals. The second most used practice in Brazilian terminals is also mentioned as highly important by Yang (2015). The *shortened moving distance of tractor-trailers or handling equipment in the CT* follows the trend of the main terminals around the world. The reason why only one terminal does not use this practice is the need for space and the area layout that separates the handling flows of ship operations and yards. *Reduction in speed of ships near the port* and *optimal CT layout for energy conservation and carbon reduction* practices, only adopted by some terminals under study, respectively, are practices in which the focus is not sustainability but operational performance. The former is applied to ships by safety regulations imposed by the port authority – which controls the entry and exit of ships at the ports – and which, for safety reasons, requires ships to reduce their speed when entering the port canal to dock. Therefore, this is an initiative from the port authorities and not from the terminals. The latter is the result of a search for better productivity in operations (decreasing the flow of vehicles), which also lowers the number of pollutants emitted by the equipment. To implement this practice, the terminal needs an area that allows storage planning with these premises – *Libra Terminals* is limited regarding this condition because it has a smaller area available, different from *APM Terminals*, which still does not measure or control its carbon emissions. Two practices that are not adopted by any terminal *layout of automatic mooring system* and *deployment of on-shore power supplies* have high implementation costs that are not part of the investment plans of Brazilian terminals. Two practices that are not used by any terminal *incentives for ships with gas emission reduction plan* and *transformation of contaminated dredging sediments into other substances* are managed by the port authority, and the terminals have no responsibility or autonomy to implement them.

Ports in other regions have a greater number of sustainability practices implemented in the Berth Area due to the active participation of the port authority and other government agencies. This factor can be identified in the studies by Cannon (2008), Yang (2015), Davarzani et al. (2016) and Schrobback & Meath (2020). This participation through incentives, investments and strategic partnerships is the main reason to explain why Brazilian port terminals are lagging behind Asian, North American and European ports.

- Yard Area

The second operational area defined by Yang (2015) is called the yard area, a place in which containers that have been unloaded or loaded are stored. The literature identifies six practices regarding sustainability in this area.

As Table 3 shows, two practices were not observed in any of the five terminals. One of the practices *use of automated handling equipment* was not implemented due to its high purchasing cost and a lack of short-term investments, and the other practice *temperature control in low energy for containers reefers* was not implemented because it depends on the ship companies (*owners of reefer containers*) to gradually modernize their reefer containers, considering that they consume a large amount of power as they are old and obsolete. Two practices

Table 3. Yard area.

YARD AREA	BTP	Santos Brasil	Libra	APM	TCP
Use of automated handling equipment	No	No	No	No	No
Conversion of diesel equipment to electric power systems	Yes	No	Yes	No	Yes
Replacement of old equipment or acquisition of electric-powered equipment	No	No	No	No	Yes
Installation of wireless remote control systems or laser sensor technology in operating system	Yes	Yes	Yes	Yes	Yes
Adoption of measures to reduce tractor-trailer engine idling	Yes	Yes	Yes	No	Yes
Temperature control in low energy for containers reefers	No	No	No	No	No

are used in most terminals, as they are mandatory by the port authority, and two others are partially used by some terminals, as they require high investment.

Yang (2015) classifies the *use of automated handling equipment* as the sustainability practice of utmost importance in the yard area, which is corroborated by Hakam & Solvang (2013), Lazic (2006), and Clarke (2006). In Brazilian terminals, however, nonautomated gantry crane equipment is used, thus requiring a manual operator. None of the terminals plans to replace manual equipment with automated equipment, as its high cost compared to the workforce does not justify the investment. The second most important practice classified by Yang (2015), also presented by Hakam & Solvang (2013) and Vujičić et al. (2013), is *conversion of diesel equipment to electric power systems*. It is possible to observe an increase in the adoption of this practice in Brazil, as some terminals have already started converting diesel equipment, while others are planning to take this measure. The importance of this practice is demonstrated by Davarzani et al. (2016), who calculate that the gain in reducing power consumption may reach approximately 30%.

It was possible to observe that Brazilian terminals present more use of two sustainability practices recommended for the yard area. The first is the *installation of wireless remote-control systems or laser sensor technology in operating system*, which are used in all terminals because wireless remote-control technology is easily understood and applied by all collaborators. Another commonly used practice is the *adoption of measures to reduce tractor-trailer engine idling*. The reduction of vehicle emissions is obtained by training operators and drivers on how to drive in a way that consumes less fuel, as well as adopting preventive maintenance and strategies that decrease the vehicles' journey. The *temperature control in low energy for containers reefers* and *replacement of old equipment or acquisition of electric-powered equipment* are practices that are less adopted in Brazilian terminals because they require high investments that are not viable at present, given the current economic situation of the terminals and uncertainties in the political and economic scenarios of Brazil.

- Gate Area

The third operational area defined by Yang (2015) is called gate area of containers, where containers that will embark are received and containers that were disembarked are removed. The literature identifies six practices regarding sustainability in this area.

According to Table 4, only one practice was not observed in any of the five terminals – the *control of harbor and stevedore operations via electronic data transmissions* practice – which requires the use of information technology, infrastructure adapted to this technology at the gate area, and a specialized workforce. From the terminals' perspective, the investment needed to adapt to this technology is too high, and the financial return is low. Due to this understanding, the practice is not applied. Two practices are used in all terminals because the

Table 4. Gate area.

GATE AREA	BTP	Santos Brasil	Libra	APM	TCP
Establishment of OCR and RFID systems to speed up the passage of tractor-trailers through the gate area	Yes	Yes	Yes	Yes	Yes
Installation of a gate assignment system to reduce external trucks' queuing time and gate passage time	Yes	Yes	Yes	Yes	Yes
Control of harbor and stevedore operations via electronic data transmissions	No	No	No	No	No
Requiring that external vehicles turn off their engines while idling and queuing to enter the gate	Yes	No	No	No	No
Use of IC tags or smart cards to facilitate passage through control points	Yes	No	No	No	No
Replacement of road modal by rail modal	No	Yes	No	No	Yes

port authority makes them mandatory, and three other practices are partially used by some terminals because they are not the port terminals' responsibility or because of a lack of investment.

The *establishment of OCR and RFID systems to speed up the passage of tractor-trailers through the gate area* is identified by Yang (2015) as the most important practice at the gate area of the terminals. This practice is adopted in all Brazilian terminals that were part of this research, as it was required by the respective port authorities to accelerate the passage of vehicles through the gates. Another practice that was found in all terminals is the adoption of *installation of a gate assignment system to reduce external trucks' queuing time and gate passage time*, suggested by Léonardi & Baumgartner (2004) and Baumgartner et al. (2008), as the port authorities required terminals to plan to receive and remove containers according to their internal handling capacity, thus enabling a reduction in queues and emissions to the environment. The other practices suggested for the gate area of the terminal present a low adoption level, as they either require high investment in equipment and technology by the terminals or are the responsibility of the port authorities or other public agencies. The *requiring that external vehicles turn off their engines while idling and queuing to enter the gate* practice is only adopted at the BTP terminal as guidance through integration videos, booklets given to drivers and information signs. Terminals are not allowed to make drivers turn their vehicles off; therefore, this practice is only guidance. The *use of IC tags or smart cards to facilitate passage through control points* is only adopted at the BTP terminal by means of a card that the driver receives at the entrance gate, indicating the address where the loading or unloading of the container should take place. In this way, drivers do not waste time locating themselves, which makes their stay at the terminal faster. The *replacement of road modal by rail modal* practice could be observed at the Santos Brasil and TCP terminals, as they have had railway lines connected to their yards since their implementation. For the other terminals to connect to the railway network, public investments must be made in the port complex to connect the existing railway networks to their yards. Currently, there are no investment plans in this regard approved by the federal government.

- Integrated Area

The fourth operational area defined by Yang (2015) is called integrated area – the corporate practice that involves the whole terminal. The literature identifies nine practices regarding sustainability in this area.

As Table 5 shows, only one practice was not observed in any of the five terminals. The *establishment of elevated roadways out of the port area* requires the involvement and initiative from the port authority and city halls, which are responsible for the traffic management plan and investments in this area. Some practices are applied in all terminals because the controlling agencies require them and they involve low investment, while others depend on each terminal's economic capacity.

Table 5. Integrated area.

INTEGRATED AREA	BTP	Santos Brasil	Libra	APM	TCP
Use of hybrid and environmentally-friendly vehicles and the use of ultra-low-sulphur fuel oil to reduce air pollution emissions	Yes	Yes	No	No	No
Restriction on entry into the port area by older vehicles, while encouraging replacement by environmentally-friendly vehicles	No	No	Yes	Yes	No
Implementation of energy conservation and carbon reduction measures in offices	Yes	Yes	No	No	No
Focus on port land, air and water quality, ecological protection, and pollution prevention	Yes	Yes	Yes	Yes	Yes
Establishment of elevated roadways out of the port area	No	No	No	No	No
Implementation and monitoring of sustainability indicators	Yes	Yes	Yes	Yes	Yes
Audits of environmental regulations	Yes	Yes	Yes	No	Yes
Environmental monitoring around the port	Yes	Yes	Yes	Yes	Yes
Generation of energy through friendly systems (wind or biomass)	Yes	No	No	No	No

The *use of hybrid and environmentally friendly vehicles and the use of ultra-low-sulfur fuel oil to reduce air pollution emissions* is classified by Yang (2015) as the most important practice in terminal integration areas. However, this practice is rarely adopted at the terminals under study due to the high cost of replacing the current fleet with a fleet of vehicles with lower indices of pollutant emission. Only the BTP and Santos Brasil terminals have developed studies on the future adoption of less harmful vehicles to the environment. *Environmental monitoring around the port, implementation and monitoring of sustainability indicators* and *focus on port land, air and water quality, ecological protection, and pollution prevention* are adopted at all terminals under study because they are demanded by the controlling agencies. In addition to being mandatory practices, Ashrafi et al. (2019) indicated that 65% of ports monitor and control the environment through

indicators, certifications and reports, a fact also observed in Brazilian terminals. These indicators are used by the port authority to compare and classify the places that require more attention, which was also suggested by Laxe et al. (2016). The lack of monitoring may result in fines or even the prohibition of operation of the terminal by the controlling agencies. The *audits of environmental regulations*, in addition to being requested by the port authority in Brazil, have become important to managers due to their possible accountability in case of environmental damage, which was also evidenced by Di Vaio & Varriale (2018) in other cases. The existence of indicators and audits allows port terminals to define their strategic goals and objectives related to sustainability, as proposed by Saengsupavanich et al. (2009) and suggested by Schrobback & Meath (2020).

The *restriction on entry into the port area by older vehicles, while encouraging replacement by environmentally-friendly vehicles* practice is adopted in two terminals, although only for informational purposes. The terminals do not have any rules regarding prevention of access, as the renewal of vehicle fleets depends on public policies of incentive and large investments from the carriers. The traffic police only inspect and fine the most severe cases. The *implementation of energy conservation and carbon reduction measures in offices* is adopted in two terminals with the use of LED lightbulbs, automatic stop water faucets in toilets and awareness programs. The *generation of energy through friendly systems (wind or biomass)* is only adopted at the BTP terminal with the use of solar panels in some buildings, such as the cafeteria and smaller facilities. As the sustainability practices in this case involve all areas of the terminal, the difficulties faced in the adoption of some of them are the high investments needed and the shared responsibility among the terminals, port authority and public agencies.

4.1. Discussion

Figure 4 shows the correlation between the size of the terminals under study in terms of the quantity of containers handled per year and the number of sustainability practices adopted. One reason why larger terminals adopt more sustainability practices is their greater financial capacity.

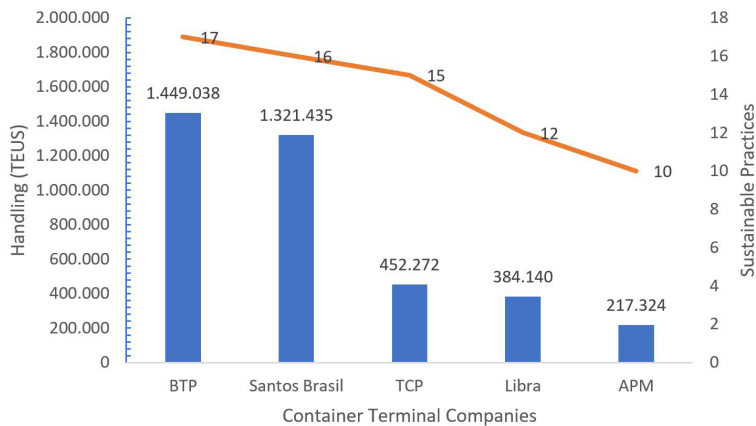


Figure 4. Correlation between container handling and practices implemented by terminal. Source: Authors.

Another observed factor that directly contributes to this correlation is that larger terminals have more structured environmental departments, with dedicated and skilled collaborators in sustainable activities. The creation and maintenance of these departments depend on the financial capacity to invest in these corporate structures. However, the smaller terminals have also been working on planning and implementing these structures. The pattern in this figure occurs in the Brazilian scenario because port terminals with greater movement and revenue have a greater likelihood of obtaining financial resources to implement sustainability practices since the responsibility for this implementation rests entirely with the terminals, unlike in other countries, where the port authority has an important role in financing such developments. Examples of this arrangement can be seen in the studies by Hakam & Solvang (2013) and Notteboom (2013). Yang (2015) highlights the need for port companies to seek a balance between economic development and environmental protection.

The BTP terminal contends that the greatest difficulties in adopting sustainability practices are a lack of state and federal regulations and the constant policy changes on the topic, which result in additional costs as the terminals adapt to the new legislation. The greatest motivation for adopting sustainable practices mentioned by this terminal is clients' growing awareness and demands, which force the terminal to adapt. The APM

terminal highlights that the driving force behind applying sustainability practices is national and international regulatory pressure, mainly related to fulfilling the terminal's lease contract. Another driving force mentioned is the value that customers attribute to the terminals that adopt sustainability practices. Through an analysis of the difficulties, it is possible to highlight the high costs of environmental programs and the lack of commitment to sustainability among the ports' top management as factors that block faster development of these practices. These perceptions corroborate those mentioned by Hou & Geerlings (2016), who highlight the importance of changing attitudes among decision makers, and by Chan & Wong (2006), who highlight budgetary and other limitations. The *Santos Brazil* and *Libra* terminals share the same perceptions, answering that the main driving forces behind adoption of the practices are national and international regulations, while the main difficulty is the high implementation costs, mainly those involving changes in equipment and infrastructure. The respondents add another difficulty – collaborators' lack of awareness at all hierarchical levels. The TCP terminal also highlights that growing awareness and customer demand are the main driving forces of applying sustainability practices and considers the main difficulty to be the high costs of purchasing new equipment and infrastructure to reduce environmental impacts.

According to the literature, companies are trying to see sustainability practices as an opportunity to improve their competitiveness, seeking motivation to overcome the difficulties regarding their adoption (Centobelli et al., 2017; Stocchetti, 2012). The framework found in Brazilian terminals only partially corroborates this statement. The results obtained demonstrate that there are several practices that are only infrequently implemented at Brazilian terminals or not implemented at all, unlike in other regions of the world where sustainability practices are applied more frequently. However, several obstacles and difficulties identified in the Brazilian case can also be found in other scenarios. The lack of integration of sustainability objectives in the decision-making and strategy-definition processes, for example, is also verified in the study by Ashrafi et al. (2019) of Canadian and North American ports. Schrobback and Meath (2020) also highlight the existence of engagement gaps in Australian and New Zealand ports regarding the implementation of sustainability practices.

It is possible to identify the existence of sustainability practices in all areas of port terminals, albeit with a smaller number in operational areas (Berth and Yard areas). The main reasons for this are related to financial and regulatory challenges, as already described in several referenced studies.

5. Conclusions

The handling of containers in Brazil and all over the world grows every year, making port terminals play an increasingly important role in world trade. Therefore, the environmental impacts that ports and port terminals may cause have also raised concerns. Thus, ports and port terminals all over the world have introduced related policies and applied sustainability practices in their operations, aiming at the sustainable growth of the container handling chain.

This empirical study, by means of multiple case studies, aimed at identifying which sustainability practices are adopted at the main container terminals in Brazil. This study included five terminals of the three main Brazilian ports, which correspond to 60% of container handling in the country. As a reference to carry out this research, the classification proposed by Yang (2015) and the sustainability practices in port terminals identified in the literature were used.

The research results show that the area referred to by Yang (2015) as integration is the area where most sustainability practices are adopted in Brazilian terminals. This statement may be explained by the obligation imposed by Brazilian legislation to control data regarding pollutant emissions and environmental quality. In the other areas of berth, gates and yards, the practices adopted are aimed at improving the terminal's operational productivity, which positively impacts the sustainability aspects.

This integration strategy of operational and environmental gains has led Brazilian ports to improve their implementation of sustainability practices, corroborating the study by Schrobback & Meath (2020), which states that the sustainability corporate strategy must focus on multiple components. The practices with a lower level of adoption by the Brazilian terminals considered in this study are those that require high investments, which are usually hindered by the terminals' lack of financial capacity. One example is the *use of automated gantry crane equipment*, which is highlighted in Yang's (2015) research but has a low implementation level in the Brazilian context.

Although the managers of Brazilian terminals consider sustainable practices to be important for the development of the terminal, there is a lack of ambitious strategies, investment plans and implementation of these practices. The driving forces that foster the implementation of practices in other terminals, such as the

development of an organizational culture focused on sustainability, operational risk management and corporate citizenship, are rarely observed in Brazil.

The lack of support and management from the government agencies that control the port areas where the terminals operate and the instability of the political scenario over the last years prevent investments due to the managers' low trust in the political stability of the country. In any case, based on the results of this research, it is possible to emphasize the evolution of the commitment to preserve the environment and progressively disseminate sustainability practices in Brazilian terminals over the last years.

This study aimed to disclose sustainability practices adopted at container terminals in Brazil, as well as provide some content, both for academia and companies, that may assist in developing new research on this theme and implementing these practices in other organizations.

It is suggested that future studies be carried out in a wider sampling universe to support the discussion on how to adopt sustainability practices and how to overcome the challenges faced when implementing these practices. Future research projects that measure the economic, social and environmental gains that sustainability practices can generate for the terminals and their surrounding communities may also be relevant.

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