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Planning and organization of road port access: The case of the Port of Santos

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ABSTRACT

Approximately 90% of the cargo in the world is carried via maritime transport, making ports a key focus for international trade and transforming port installations into constant objects of academic study. One of the key aspects of port management is the issue of access. With an increase in cargo volumes, many port cities have experienced constant bottlenecks due to the lack of adequate space for port operations. Considering that the terrestrial access problem faced by Port of Santos has not yet been analyzed, this research aims to evaluate the logistical and environmental effectiveness of the organizational method adopted in Santos to address this problem, having as reference the solutions adopted by ports in developed countries. The organization method of terrestrial access adopted in Santos proved to be an effective alternative from a logistics operation perspective with the implementation of the regulating yard. On the other hand, the condition of a port of an emerging country strongly influence the approaches taken to address environmental issues, where cultural and economic issues hamper the adoption of measures to reduce harmful emissions in Santos.

1. Introduction

Approximately 90% of the cargo in the world is carried via maritime transport, making ports a key focus for international trade and transforming port installations into constant objects of academic study (Kaluza et al., 2010). The increase in commerce among countries demands logistics structures with high levels of operational performance. The use of new technologies to maximize capacity utilization and rationalize transshipment operations for cargo flows has brought an increase in efficiency to port operations. A current challenge that modern port managers must face is the planning of measures that optimize port activities in a way that causes the least amount of disturbance possible to the everyday urban routines in the cities where they are located (Debrie and Raimbault, 2015).

One of the key aspects of port management is the issue of access. With an increase in cargo volumes, many port cities have experienced constant bottlenecks due to the lack of adequate space for port operations. This situation has existed since the 1980s and reached its peak in the year 2000 when access to the port of Los Angeles/Long Beach in California (USA) was closed (Giuliano and O’Brien, 2007). Subsequently, other American (New York and Houston, among others) and European ports (Antwerp and Rotterdam, among others) faced similar problems. With the increase in trade activity from emerging economies since 2009, ports in India, China and Brazil, specifically the Port of Santos, which is the largest port in the Southern Hemisphere, have faced similar inconveniences. The bottlenecks associated with port access have produced several academic studies. These studies mainly considered further access control actions that could be implemented to improve access management by either increasing the operational space of the port or by applying an access restriction system (Chen et al., 2011).

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As an attempt to control the terrestrial traffic, each port developed its own access control system based on its particular operational layout, governance requirements, and environmental restrictions. Despite their varying characteristics, these access systems demonstrated satisfactory results and revealed that each port required a specific solution to suit its own context (Phan and Kim, 2015). In 2014, due to an increase in agricultural production, the Port of Santos adopted its own terrestrial access control system under the control of the port authority to address the volume of trucks originating from Brazil (CODESP, 2018a).

Despite stemming from a single problem, the method adopted by the Port of Santos produced a variety of solutions that should be studied to catalog the best practices for terrestrial port control from the perspective of a large-scale port located in an emerging country.

Considering that the terrestrial access problem faced by Port of Santos has not yet been analyzed, this research aims to evaluate the logistical and environmental effectiveness of the organizational method adopted to address terrestrial access, having as reference the solutions adopted by ports in developed countries.

This paper is organized as follows. The next section presents the theoretical background that was the basis for this research. The third section describes the methodology adopted to develop this work. The fourth section presents the context for the Port of Santos. The fifth section presents an analysis of the results obtained, and finally, the sixth section focuses on the final considerations.

2. Theoretical background

2.1. The international port sector and port management in emerging countries

In a globalized world, where distances are virtually decreasing, ports play a significant role in sustaining the growth of a country's economy. As a typical intermodal platform, a port is a complex system consisting of a vast range of resources used in a variety of operations that continuously run 24 h a day and 7 days a week (Zhang et al., 2013). Many important factors, which are not always easy to control, may affect the quality of the services offered and the overall efficiency of the system. The successful management of any maritime port depends on harmonizing the transport demand and supply, which requires efficient planning, forecasting, and the quantification of the infrastructural services needed (Fancello et al., 2011). This impacts the use and flexibility of port capacity, the cost-benefit ratio, the port's bottlenecks, and the waiting time of vessels (Jugovic et al., 2011).

Kaluza et al. (2010) report that international maritime lines have recently been aligned according to the cargo volume transported to hinterlands from central ports to improve logistical facilities and reduce costs. The authors define the betweenness centrality of a port as the number of topologically shortest directed paths in the network that pass through this port. Due to the physical distance between ports in the Northern and Southern Hemispheres, hubs are located based on reducing journey times, attracting navigation routes, gaining economies of scale, increasing import and export business, and reducing shipping costs, thus enabling hubs to supply smaller ports with regional demands and provide links to long-distance navigation lines. In developed countries, this decision process was successful due to advanced port structure, knowledge, understanding of port logistical constraints, economic stability, among others (Castro-Gonzáles et al., 2015). In the South American continent, Santos is the only port that receives all the international navigation lines and is a central port for connecting to other global ports, thereby fostering commerce among regional ports around the continent (see Fig. 1).

The infrastructure of a port is developed for the zone of influence that it intends to cover according to the foreign trade requirements in the country (Witte et al., 2014). In developed countries, a large part of international cargo is shipped in containers, while emerging countries have a large proportion of bulk cargo, which is typical for raw material exportation (Schoenherr et al., 2012). Differences are also seen in transportation modes – while developed countries have a balance between rail and road transport (Zehendner and Feillet, 2013), approximately 60% of the cargo in Brazil is moved by road (BRASIL, 2018). Chart 1 lists the characteristics found in emerging countries (Schoenherr et al., 2012; Castro-Gonzáles et al., 2015).

2.2. Port accesses

Port access is an important part of port logistics studies and includes the consideration of roads, railways, and pipeline networks. The maximum capacity for transportation volume and terminal operational activity is being reached and problems in operational flow, urban congestion, and environmental problems are being experienced (Giuliano and O'Brien, 2007). Port cargo handling takes into account various types of cargo and the availability of different modes of transportation (Lee et al., 2012). To obtain a more sustainable chain of transportation, the departments that coordinate these activities aim at adopting more sustainable modes and fostering the use of intermodal transport (Bouchery and Fransoo, 2014). Port operations are associated with issues related to the environment (exploitation of resources), economic system (investments and technological development), and sociocultural interests (institutional exchanges), revealing that the continuous development of sustainability is part of a process that manifests locally (Kim et al., 2011). Environmental impacts that originate from port activities are measured as instantaneous (e.g., noise), invasive (e.g., hydrocarbons), permanent (e.g., visual aspects), and cumulative (e.g., particles emitted). Some impacts, such as the emissions from vehicles, can be easily measured because they are related to physical aspects (Hou and Geerlings, 2016).

As most port cargo handling activities involve road transport, the number of trucks required in a port area over particular time periods is a decisive factor that generates or even worsens congestion that occurs at distinct vehicle arrival and departure times, affecting the port's primary area and other access roads (Phan and Kim, 2015). The road transport mode features door-to-door service, high availability and the capability to transport different types of cargo; it is recommended for short- and medium-distance shipping, as it involves less cargo handling and lower demands for packaging (Teodorovic and Janic, 2017). Phan and Kim (2015)

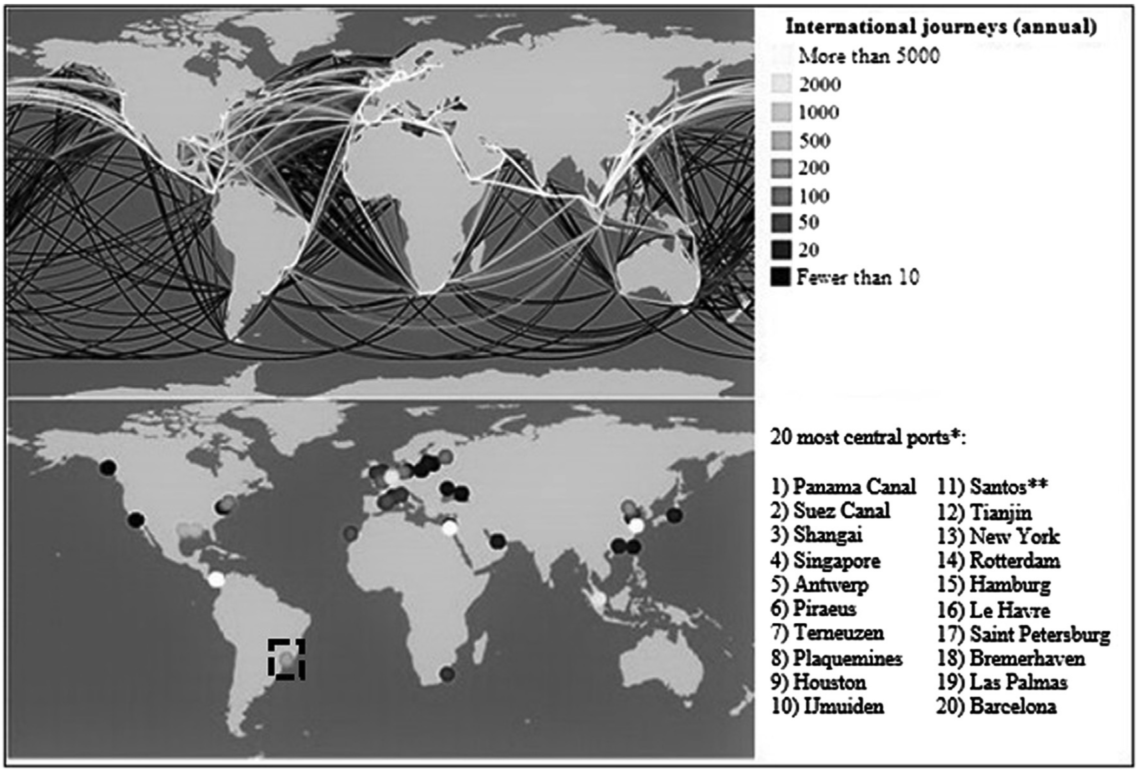

Fig. 1. Routes, ports and betweenness centralities in the global cargo ship network. *Central ports are those most interconnected ports in the global cargo ship network. **Port of Santos dashed in the map.
Source: Adapted from Kaluza et al. (2010).

Operational	Territorial	Structural	Economic
Lack of a skilled workforce	Space available for territorial growth	Lack of long-term projects	Complex economic sectors
Unbalanced transport matrix	High population indices	Predominance of primary operational structures	Corruption and bureaucracy in the government
High availability of manual labor	Cultural barriers	Difficulty in allocating investments	Concentration of agricultural or manufacturing production with low aggregated value
Inefficient resource management	Own unique social characteristics	Preference for maintenance instead of improvement	Trade union protectionism

Chart 1. Characteristics of an emerging country.
Source: Adapted from Castro-Gonzáles et al. (2015) and Schoenherr et al. (2012).

mention that several operations influence the access of trucks to ports, such as internal loading and unloading at terminals, transshipment load operations, and operations involving empty containers. The most efficient projects involving port access are those based on the expansion of storage areas for terminals and the scheduling of trucks to manage access (Giuliano and O'Brien, 2007). Chen et al. (2012) state that there are two main limitations in the expansion of the physical capacity of terminals and ports: the space for expansion is not always available in the port area, and the lack of control may cause congestion within the terminal itself. Additionally, the implementation costs of a truck scheduling system for access control are lower than the construction and installation costs of a terminal for receiving trucks (Namboothiri and Erera, 2008). According to Bouchery and Fransoo (2014), even though no correlation has been established among long-distance intermodal transport, gas emission reduction, and the total cost of the operation, road transportation is the most visible symbol of pollution. Long-term management strategies must consider harmful

Reference	Port	Movement**	Access modes**	Management method for the terrestrial access
Regan and Golob (2000), Giuliano and O'Brien (2007), Morais and Lord (2006), Chen *et al.* (2011), Lee *et al.* (2012)	Los Angeles and Long Beach	General cargo: 92% Solid bulk: 1% Liquid bulk: 8%	Road: 57% Railway: 39% Others: 4%	Incentive access during nonpeak hours
Osbay, Yazici and Veras (2006), Ku and Arthanari (2016), Phan and Kim (2016), Morais and Lord (2006)	New York and New Jersey*	General cargo: 48% Solid bulk: 43% Liquid bulk: 9%	Road: 71% Railway: 25% Others: 4%	Timetable linked to the berth of vessels and a restriction on the number of vehicles on the road
Huyhn and Walton (2008), Morais and Lord (2006)	Houston	General cargo: 72% Solid bulk: 11% Liquid bulk: 17%	Road: 77% Railway: 19% Others: 4%	Access authorization according to the availability of stowage equipment
Karafa (2012), Morais and Lord (2006)	Newark and Elizabeth*	General cargo: 46% Solid bulk: 43% Liquid bulk: 11%	Road: 69% Railway: 25% Others: 6%	Timetable linked to the berth of vessels and a restriction on the number of vehicles on the road
Morais and Lord (2006)	Oakland	Container: 100%	Road: 63% Railway: 29% Others: 8%	Mandatory for all companies that transport containers
Morais and Lord (2006)	Seattle and Tacoma	General cargo: 94% Solid bulk: 3% Liquid bulk: 2%	Road: 25% Railway: 64% Others: 11%	Control of road and railway terrestrial access
	Miami	General cargo: 89% Solid bulk: 9% Liquid bulk: 1%	Road: 65% Railway: 29% Others: 6%	Shared with all port operators
	Jacksonville	General cargo: 74% Solid bulk: 18% Liquid bulk: 8%	Road: 64% Railway: 31% Others: 5%	Shared with all port operators
Zehendner and Feillet (2013)	Marseille	General cargo: 87% Solid bulk: 12% Liquid bulk: 1%	Road: 82% Railway: 10% Others: 8%	Maximum allocation of trucks at the port's area

Chart 2. Summary of the literature on terrestrial access management methods. *Jointly managed by the *Port Authority of New York/New Jersey*. **Consolidates data obtained from the *Bureau of Transportation Statistics*, 2017. "Others" includes waterways, airways and pipelines.

emissions and develop vehicles that optimize fuel consumption, among other measures (Demir et al., 2011). To decrease the environmental impact of road transport in port operations the total amount of transportation must be reduced by altering the transport matrix and/or operators' behavior, reducing the impact of specific modes through new technological solutions, and improving the management of the environment through territorial planning (Hou and Geerlings, 2016).

2.3. Organization methods for terrestrial port access

As the efficiency of maritime transportation depends on the interaction of the port with its hinterland (Regan and Golob, 2000), this research develops a summary of literature about the organizational methods adopted for terrestrial access by several ports, including the types of cargo and the access modes used (see Chart 2). Although each port has adopted a different port scheduling method, differentiated mainly by the type of technology adopted (RFID - Radio Frequency Identification, EDI - Electronic Data Interchange, and OCR - Optical Character Recognition, among others), all the ports in this study adopted a scheduling system to address access control. Among the practices studied, it is possible to comment on the access control according to the availability of stowage equipment, increase in the use of technology, responsibilities of the regulatory agency, penalties applied to unscheduled vehicles, and denial of port access to unscheduled vehicles.

To improve the logic of the comparative structure, the listed ports were grouped according to the main cargo type and the transport mode. In this way, it is possible to obtain a more accurate perspective on the results from the terrestrial access controls that were applied, since the modes and cargoes require specific settings for movement and the impact of these actions may be unequal in

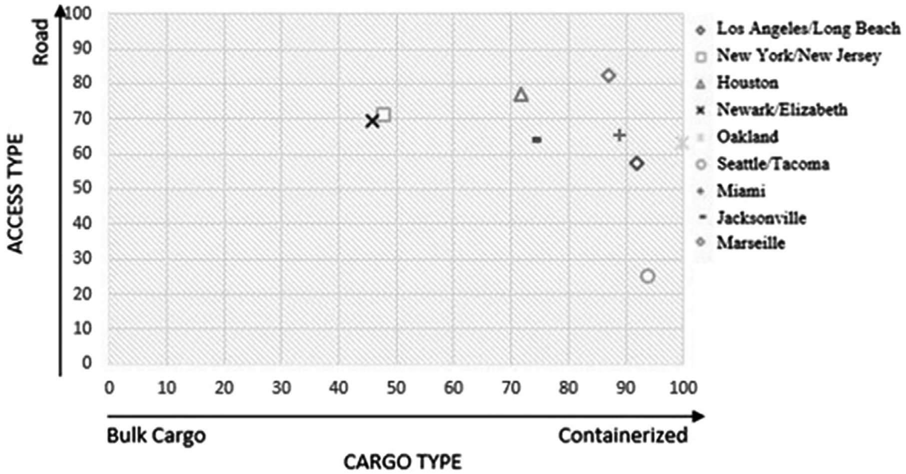

Fig. 2. Dominance matrix of the ports in the study.

ports with different economic strategies. Fig. 2 presents the dominance matrix in terrestrial port transport among the ports under study as well as its grouping.

3. Methodology

The basis for this research was established by a literature review conducted using the Scopus, Web of Science and ProQuest databases with the following keywords: *port congestion*, *truck appointment systems*, *port authority*, *truck emissions*, *port-city relationship*, *port development* and *effectiveness port operations.* The articles considered relevant for the purposes of this study were evaluated and classified, as shown in Chart 2, and formed the base for creating the reference model for the research and developing the protocol used for collecting on-site data and interviews. Data collection at the Port of Santos was carried out by means of semi-structured interviews, in loco observations, documentary analysis, and analyses of data extracted from the websites of the players involved. To increase the credibility of the data presented, a triangulation of the data obtained was carried out. Quantitative data were used to help analyze and support the statements obtained during interviews. Interviews were conducted at the *Companhia Docas do Estado de São Paulo* (CODESP) the port authority of Santos with executives from the logistics board. Data related to the environment were obtained at the environmental company of São Paulo State, *Companhia Ambiental de São Paulo* (CETESB), by means of interviews with the executives. On behalf of the City Hall of Santos, executives from the Secretary of Port Affairs, Industry, and Commerce were interviewed. Traffic data from the Port of Santos were supplied by the Regulating Agency of Terrestrial Transports of the State of São Paulo - *Agência Reguladora dos Transportes Terrestres do Estado de São Paulo* (ARTESP), the state agency responsible for the concession for road access to the port. The concepts behind the port's access control methods were discussed in each interview in order to list all the factors that could affect road access for receiving cargo, and the discussions included the logistical and environmental impacts and the consideration of the port as an inclusive component of the city in which it is located. To fulfill the purposes of this research, members of the logistic board of the *Port Authority of New York/New Jersey* (PANYNJ) were interviewed by e-mail. Operational data from the *Truck Service Center* were extracted to obtain traffic data of the Port of New York/New Jersey and of the Port of Newark/Elizabeth. Environmental data from the Port of New York/New Jersey and the Port of Newark/Elizabeth was provided by e-mail by the *New York State - Department of Environmental Conservation* and by the *New Jersey State - Department of Environmental Protection*, respectively. Chart 3 summarizes the sources of the data obtained.

4. The Port of Santos

The Port of Santos, located in the State of São Paulo in southeast Brazil, is the largest port in Latin America and is responsible for 30% of Brazilian trade (CODESP, 2018b). The port has 46 terminals, including 6 container terminals, and 73 port operators and is divided into 5 administration zones. The maximum operational draught in the channel is 13.20 m, and the minimum is 12.20 m. As the port is the main foreign trade hub for the country, it receives several types of cargo (Table 1), and its movement diversity allows for more facilities and flexibility than other ports in the area. Simultaneously, it is possible to berth and operate 33 vessels simultaneously because of the uninterrupted transit in the channel. The primary area of influence of the Port of Santos includes the states of São Paulo, Minas Gerais, Mato Grosso, Mato Grosso do Sul, Goiás, and the Federal District, which represent 75 million people, 67% of the Brazilian GDP, and 56% of the Brazilian trade balance in terms of monetary value.

The port has five access roads. The Imigrantes (SP-160) and Anchieta Highways (SP-150) are the main ones, and the interconnecting access roads are the Cônego Domênico Rangoni Highway (SP-248), the Rio-Santos Highway (BR-101), and the Padre Manoel da Nóbrega Highway (SP-055). Its railroad network comprises the MRS Logística, ALL, and Portofer rail lines. It also has waterway access (with transshipment) through the Tietê-Paraná waterway. There is pipeline access through the sidings of Petrobras

	Interviews	Data
Port of Santos		
CODESP (Santos Port Authority)	Executives from the logistic board	No
CETESB (State Environmental Company)	Executives from the operational area	Regional air PM concentration
Santos City Hall	Secretary of Port Affairs	No
ARTESP (State Agency of Terrestrial Transports)	No	Traffic
Port of New York/New Jersey		
Port Authority (PANYNJ)	Members of the logistic board	Traffic
DEC/NY (Department of Environmental Conservation)	No	Regional air PM concentration
Port of Newark/Elizabeth		
Port Authority (PANYNJ)	Members of the logistic board	Traffic
Dep/NJ (Department of Environmental Protection)	No	Regional air PM concentration

Chart 3. Summary of interviews and data collected.

Table 1
Movement in the Port of Santos (in tons)..
Source: Adapted from CODESP (2018a)

	General cargo	Bulk solids	Bulk liquids	Total
2008	33,469,516	34,021,589	13,490,897	80,982,002
2009	29,590,887	38,315,020	15,114,032	83,019,939
2010	35,231,270	45,034,423	15,759,565	96,025,258
2011	36,041,648	45,031,773	16,096,887	97,170,308
2012	38,038,034	50,798,166	15,707,583	104,543,783
2013	40,959,313	57,087,476	16,031,095	114,077,884
2014	43,720,432	52,455,899	14,983,154	111,159,485
2015	45,587,074	58,752,046	15,592,760	119,931,880
2016	43,856,416	54,187,843	15,771,493	113,815,752

Transportes S.A. – Transpetro. Currently, 64.4% of the cargo is moved into the Port of Santos by road, 26.3% by railway, and 9.3% by pipeline (Fig. 3).

To compare it with its peers in this research, the Port of Santos was positioned in the dominance matrix in Fig. 4 according to the type of cargo moved and the participation of the access modes. Based on the data extracted and the literature on the ten ports researched, the two ports with the most similar characteristics to Santos are the Port of New York/New Jersey and the Port of Newark/Elizabeth. These three ports will work as the basis to quantify the port access data on operational and environmental subjects, not excluding the others under the qualitative aspect of the research.

5. Results

This research aims to evaluate the logistical and environmental effectiveness of the organizational method adopted to address terrestrial access, having as reference the solutions adopted by ports in developed countries. In addition to the data obtained by interviews, on-site observations, documents and websites of the players involved, numerical data on traffic volume and particulate emissions were obtained to verify if, with the adoption of the respective terrestrial access method, some variation in the indicators supporting the conclusions obtained through the qualitative analysis can be observed. Thereby the data were organized in two graphs containing historical series of five years of terrestrial port operation, two years before the implementation of the access system, the current year of adoption of the method and the two subsequent years. The first part of the data used is the movement of commercial

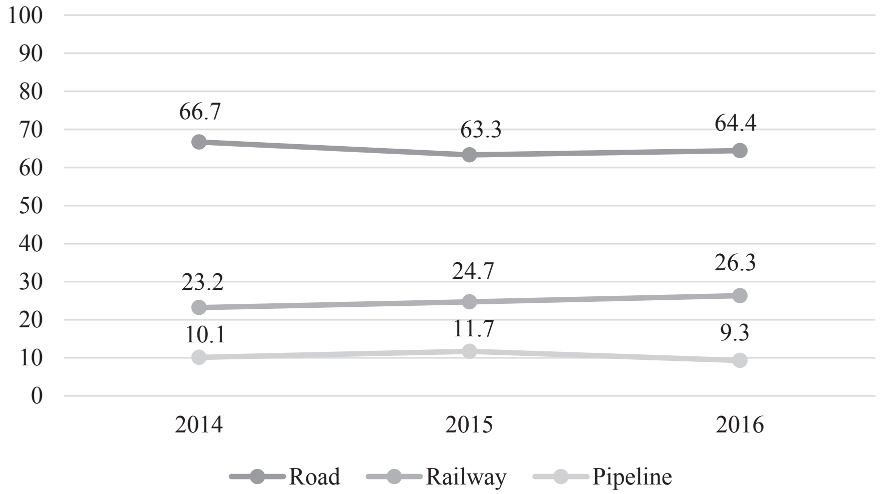

Fig. 3. Participation of the transport modes in the Port of Santos (in %).
Source: Adapted from CODESP (2018a).

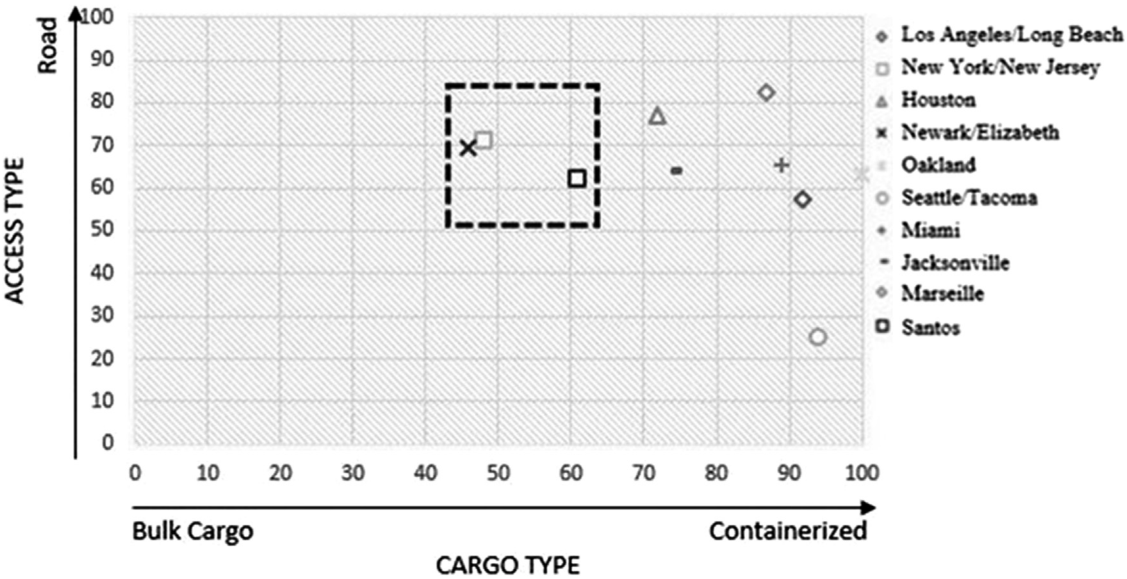

Fig. 4. Port of Santos in the dominance matrix.

vehicles that access the port system, given by a daily calculation that applies a flexible sum from the first month of the analysis and is corrected according to the relationship between the traffic flow and density of the roads (Fig. 5). The second part of the data is the daily particulate emissions measured at the air quality monitoring stations installed close to the pollution sources indicated by the

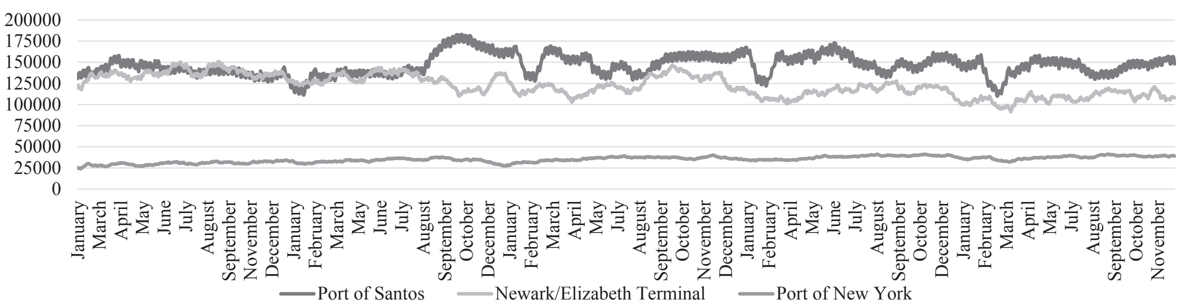

Fig. 5. Comparative graph of the flow of trucks for the ports in the study (in quantity).

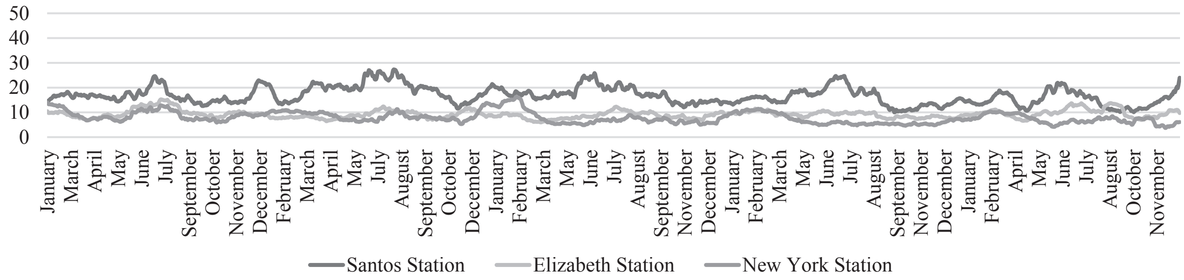

Fig. 6. Comparative graph of average values of PM 2.5 for the ports in the study (in μg/m^3).

actors considering the particulate matter (PM) with a diameter of 2.5 μg/m^3 or less of the pollutant measured (Fig. 6).

5.1. Port of Santos

Regarding the Port of Santos, the scheduling system was created with operation windows defined by the movement capacity. In addition to imposing fines to the terminals and traffic-generating centers, the scheduling system received data about available idle areas at the secondary port area for the establishment of regulating yards, which are used to smooth the cyclical demand for vehicles. These yards, leased to the private sector, have their own contracts with the terminals and enough space for vehicles to wait until they are granted authorization to access the terminal. The crossing route to be taken through the yard is mandated and is controlled by RFID monitoring as part of the scheduling system, thus making the system more robust. The daily data obtained covers the period from January 2012 to December 2016, including the implementation of the terrestrial access method, which occurred during February 2014 at the Port of Santos (see Figs. 5 and 6). In terms of the logistical aspects of the port access process, Santos presents an organization with low variation in the quantity of vehicles and a stable average vehicle flow. Between 140,000 and 160,000 vehicles

		ADOPTION			CONSIDERATIONS
		Santos	NY/NJ	N/E	
OPERATIONAL	Scheduling with intelligent time slots dependent on maritime attraction and storage availability	No	Yes	Yes	In Santos, there is no application due to weather and operational issues
OPERATIONAL	Access restriction for noncompliant vehicles on the access road	No	Yes	Yes	In Santos, consider the road concessionaires
OPERATIONAL	Use of RFID tags with real-time monitoring	Yes	Yes	Yes	Technological innovations with good control mechanisms
OPERATIONAL	Scheduling with scales defined by the maximum movement capacity of the terminals	Yes	No	No	In New York/New Jersey and Newark/Elizabeth, the scheduling methods are more effective
OPERATIONAL	Vehicles must go through regulating yards	Yes	No	No	In New York/New Jersey and Newark/Elizabeth, consider the lack of areas for expansion
ENVIRONMENTAL	Access restriction of Euro IV vehicles or older on the access road (secondary area)	No	Yes	Yes	In Santos, consider cultural restrictions and labor regulations
ENVIRONMENTAL	Operate on fleet renewal	No	Yes	Yes	In Santos, consider the lack of resources for investments
ENVIRONMENTAL	Vehicles must go through regulating yards	Yes	No	No	Consider areas for expansion

Chart 4. Summary of the strategies used by ports in this study.

access the system monthly with an average of 4.5 thousand vehicles/day on a 57 km road linking the origin (the Rio Grande access station in Planalto) and destination (the industrial district of Alemoa). The adoption of access control occurred due to the intense daily flow during 2013 and the enactment of a new Port Law, which resulted from the commodities operations. However, after going through considerable difficulty in the first months of 2014, the scheduling system of Santos presented high stability in the traffic flow, without large variations in the following years. Even with the flow of trucks increasing due to the growing cargo volumes in Santos, the system presents a stable average daily flow overall, possibly due to the efficient adoption of access control. Although the historical series reveals sustainable growth in the number of vehicles, port access together with growth in the number of commercial and passenger vehicles may reduce the efficiency of the system in the future. This evidence motivates the port authority to carry out investments to segregate the traffic at the entrance to the city. From an environmental perspective, the historical data obtained shows that port activity has had a strong impact on air quality considering that the area measured is contiguous with the residential zone of the city. In the second part of 2013, the air of the area analyzed exceeded the maximum limit (over 50 $\mu g/m^3$) in every period, what may be an indication of the impact of an unorganized increase in the flow of trucks. After the second semester of 2013, there were no occurrences of bad air quality (an index over 50), but the air in the region still has high rates of particulate matter.

5.2. Port of New York/New Jersey

The access control system for the Port of New York/New Jersey, which in this study consists of the Red Hook Marine Terminal of Brooklyn and the marine container terminals of New York – Howland Hook and Port Jersey, was implemented on July 1st, 2013, with the implementation of the *Sea Link system*. On July 13th, 2015, the Port Authority changed the technological access system for port truck passes, keeping the original listing. The registrations are carried out electronically through the *Drayage Truck Registry* (DTR) form and trucks are then automatically linked to a vessel scale or allowed to move an empty container. This information is added to an electronic RFID tag and placed on the vehicle's windshield. The system is managed by *Sustainable Terminal Services Inc*., which is a company created by the port terminals to efficiently and jointly manage the port system, under the supervision of the *Port Authority of New York/New Jersey* - PANYNJ. The sector responsible for the scheduling system is the PANYNJ *Truck Service Center*, which established the access regulations for vehicles in a 2013 resolution (updated in 2015). According to the *Truck Service Center*, the guidelines include the following rules: (1) a vehicle cannot access the port without an RFID tag; (2) each vehicle may have only one RFID tag linked to a DTR; (3) the access of vehicles with engines manufactured in 1995 or before is banned; (4) only vehicles equipped with engines within the emission standards specified by the *Environmental Protection Agency* for heavy vehicles are allowed to use the DTR form registry; and (5) if a vehicle is denied access to the terminal, the driver receives a document that explains the reason for the refusal. All drivers are registered in the *Transportation Worker Identification Credential Registry*, which is mandatorily connected with the DTR. Interstate Road I-298 and the State Roads 25 and 440 provide the access route to the port terminals. The route distance is approximately 62 km. The port operates 24 h a day, 7 days a week, with the operations divided into four shifts of 6 h each (7 h/13 h, 13 h/19 h, 19 h/1h, 1 h/7h). The access time slots are defined based on shift structure and link the truck to the container to be transported and the transportation equipment used at the berthed vessel. It is important to highlight that this method is extremely efficient for very populated areas, such as the region of the two ports, as they have little area available for expansion. The effectiveness of the scheduling method used by the Port Authority (the manager of the two ports) is directly influenced by its regulation. The scheduling system link to the vessel berths is an important logistics solution that results in the Port Authority totally controlling the truck movement, decreasing the incidence of congestion. However, this method is only applicable in operations that are not subject to storms or various circumstances that may suspend or halt port operations. According to the historical data obtained, the two ports did not address long waiting lines or blockages at access gates due to the uncontrolled arrival of vehicles. Environmentally, PANYNJ has initiatives such as a replacement program for trucks manufactured before 2007 and an environmental program for trucks, which, together with the *United States Environmental Protection Agency* (EPA) standards, prevents the access of older trucks and fosters the use of renewable fuels to decrease harmful emissions. The daily historical data ranges from January 2011 to December 2015, with the adoption of the system taking place on July 1st, 2013 (Figs. 5 and 6). There is continuous growth in the number of trucks, rocketing from 25,000 to 40,000 per month without peaks or valleys in the numbers. There was no change in the flow of trucks after the implementation of the access method in July 2013. Possibly, the strict rules for trucks to access the primary area of the port may result in tighter access control at the trip origin, as the scheduling system is complementary to the government policies mentioned by PANYNJ employees. Regarding the overall efficiency of the system, PANYNJ states that all port operators are aware that the scheduling guidelines enable a decrease in waiting lines and a reduction in delays of vessel loading, bearing in mind that the system schedule is based on the berth and the start time of the operation. This creates an interdependent relationship between the arrival of trucks and berthing of vessels. In terms of the control of harmful emissions, the data from the air quality monitoring station, PS 314, located in the district of Brooklyn, indicated steady emissions levels (see Figs. 5 and 6). After adopting the terrestrial port access control system, there is no decrease in particulate matter emissions (PM 2.5). It is also possible that the extent of the measured area and the air masses influence the dispersion of the particulate matter.

5.3. Port of Newark/Elizabeth

The access to the Port of Newark/Elizabeth, which includes the Port of Newark and the marine terminal of containers of Elizabeth in this study, is managed by PANYNJ with the same regulations and infrastructure projects as those at the Port of New York/New Jersey. As the scheduling of trucks was implemented simultaneously in both ports, the dataset spans from January 2011 to December 2015 (Figs. 5 and 6). In terms of the access system to the port complex, the Elizabeth terminal has the largest cargo volume and number of cargo movements since it is one of the largest port facilities in the US. From a logistics perspective, the daily truck traffic that accesses the port system has a slow pace and a high variation in the months studied. According to members of logistic board, large fluctuations in the months after November 2012 may reveal a change in the ports attractiveness to shippers and in the contracts between the ship owners and terminals since the scheduling system is based on a vessel's operational time slots. The total traffic fell from 140 to 100 thousand/month until October 2012, and after this decrease, the data shows many fluctuations in the number of vehicles, even after the adoption of the scheduling system. In August 2013, the traffic returned to its normal level at the beginning of 2011, and it returned to an average of 100 thousand/month in 2014, remaining steady throughout 2015, confirming the statements of the interviewees. Regarding emissions measures, the indicators from the Elizabeth monitoring station, which is located near the main access gate to the terminal, revealed a low concentration of pollutants. However, a moderate concentration was reached for a few periods, as seen in the Fig. 6, (higher than 25 and lower than 50 $\mu g/m^3$). After the adoption of the scheduling system, the concentration of particulate matter increased by 14%, and there was a significant worsening in air quality in 2015.

5.4. Analysis and discussion

Initially, considering the qualitative data and the traffic volume, the Port of New York/New Jersey may be treated differently from the other ports as it presents a medium-level stable flow and the number of trucks transiting the port roads is highly stable. The logistics staff of the Port of New York/New Jersey considers that the adopted system is effective and overestimated from a logistics perspective, because of a low number of occurrences of access waiting lines, what can be observed in the data of Fig. 5. Regarding to the other ports, Santos and Newark/Elizabeth, the data shows two ports with a similar number of vehicles and different arrival processes. The Port of Santos access is fast paced, i.e., there is no significant daily variance that causes a waiting line to extend along the access road. The fast pace that Santos presents from the beginning of the series indicates that there is a stable average flow at this port. Due to the disturbances observed in September of the second year of the series, measures were necessary to contain the growth in the number of vehicles. The adopted measures did not decrease the number of vehicles, which is the because of economic activity, but stabilized the system. According to the managers of CODESP, the port obtained a significant operational gain with the adoption of the scheduling system. On the other hand, the average number of vehicles that access the Port of Newark/Elizabeth is highly variable on a daily basis, possibly leading to a higher frequency of waiting lines at this port compared to Santos. The data do not clearly indicate an improvement in the access flow with the adoption of a scheduling system. Port managers stated that the decline in maritime demand might have led to a reduction in the number of waiting lines. In Santos, since the yards do not reach their capacity, waiting lines may not occur at the terminals' gates, which may explain the fast pace of vehicles in the historical data and the overall effectiveness of the operation.

Important factors should be highlighted in the logistics comparison among the methods. Even if the scheduling system exercises a minimum control on the arrival order, the regulating yard transfers the waiting line to a confined area, which is a fundamental factor for a port with the hinterland of Santos, as told by the staff of CODESP. According to the local managers, there is still abundant space available in the supporting area, a characteristic observed in emerging countries. Therefore, the terminals that should have internal parking lots but do not because they are in an area adjacent to the city endorsed the establishment of the yard as the most appropriate measure for the Port of Santos. Another factor is the port administration, where CODESP operates under legislation that limits its action (another limit identified in emerging economies), whereas the PANYNJ has a strong mandate. PANYNJ manages not only the two ports in this study but also the port access roads, bridges, and tunnels in the states of New York/New Jersey. PANYNJ manages a railway and a metropolitan passenger transport system and operates in the real estate market in addition to other activities. This wide business range enables it to raise resources to invest in port projects and decreases state interference. As it is a bi-state company that controls both land and sea areas, it decreases the impact of sensitive conflicts between the ports and cities. Possibly, the port management method found at the PANYNJ comes from the decades of experience gained during its uninterrupted presence in the region. It is focused on long-term planning and the stage of economic development. These characteristics cannot be observed in the investments made by developing countries.

The implementation of a regulating yard would be an unnecessary and complex strategy for the Port of New York/New Jersey considering the small variations in the data demonstrating that it has a history of defined arrival times. At the Port of Newark/Elizabeth, a regulating yard would be effective. However, the local authority of the Port Authority declares that there is no area available for such expansion. A regulating yard can be an effective logistics tool, but its construction requires more resources than does the implementation of an electronic scheduling system. Therefore, its adoption must be evaluated from an economic perspective. The access rules of the ports managed by PANYNJ are effective in that context, in which the overall access control is performed at a microscopic level, i.e., at the vehicle level. High fines and the revocation of access for noncompliant trucks are measures with practical results, which can be done by developed countries with less freelance truckers mass. However, they would have a limited effect in Santos because the average distance covered by a truck between the production center and the port of Santos is larger than those covered at the two other ports, evidencing an emerging unbalanced modal transportation matrix. Therefore, an expansion of the port area is necessary to accommodate these vehicles. If implemented at the Port of Santos, a schedule based on the vessel berth scale could be a prejudicial factor in the system's operation, considering that the scale of vessels changes regularly due to storms and other operational problems.

As seen in the literature, the objective of the first access control system at a port was to reduce harmful emissions (Port of Los Angeles and Long Beach, in the 2000s) to improve air quality and positively influence the relationship between the port and the city. This is especially important in densely populated urban areas, such as the three regions under study. As observed in the cases studied, the strategy adopted by the ports of New York/New Jersey and Newark/Elizabeth consists of two important measures. The first prohibits trucks manufactured before 2007 from accessing the roads under its jurisdiction, which cannot be done because the amount of freelance truckers in the Port of Santos area. This restriction has an immediate impact on the level of emissions by removing vehicles that do not comply with the road's regulations and forcing companies to replace vehicles. The second measure concerns programs for fleet renewal. PANYNJ acts according to its clean logistics goals to reduce the age of the fleet that accesses the ports. Their regulations have clauses governing the scrapping of vehicles and the monitoring of emissions using the RFID tags. These are important rules that contribute to the environmental success of the measure, even though it is not possible to confirm this with the historical data. These measures do not directly link to the structure of the access methods but they reflect the environmental responsibility of port authorities. Located in densely populated areas, the importance of connecting environmental, social, and economic perspectives as part of a long-term permanent project can be identified in the ports of New York/New Jersey and Newark/Elizabeth. This type of approach is not found in the Port of Santos.

The comparative daily average of the data shows that the port regions of New York/New Jersey experienced an increase in the air quality indices, which lacked high emission peaks but had a lower rate of increase compared to that of Santos. Even if the port activity is not the main source of fine particulate emissions, the position of the stations allows the assessment of a part of the pollution caused by port activity. Observing the five years of operation, there is no indication that any improvement in air quality occurred in any of the three regions due to the implementation of terrestrial port access control. Analyzing the data obtained in the cases studied, it is possible to say that Santos has more environmental problems due to an apparent rise in emissions levels in the last two years compared to its peers, especially because its scheduling method currently does not have a specific program that focuses on the reduction of pollutants. However, port activity proves to be challenging from an environmental perspective in all the areas under study.

The port region of Santos is the most affected from environmental impacts among the three cities. Only port activity was considered as polluting in the city of Santos, while in the secondary area of the ports managed by PANYNJ, there is developed industrial activity. The inspections carried out by the CETESB, the environmental company of São Paulo State, on the roads that provide access to the port are followed with strong punitive measures imposed on the owners of polluting vehicles. However, freelance truckers cause the main environmental problems with terrestrial access in Santos, and this issue is far from being solved. Freelance truckers are still being treated as the base of the economic pyramid, a characteristic of developing countries. A waiting line of trucks with engines idling considerably increases harmful emissions, as mentioned by the executives from CETESB (Fig. 6). The regulating yard removed vehicles from the road but it is possible to conclude that it is only moderately effective environmentally.

As a measure of environmental control, regulating yards would not be very effective for access control at the ports managed by PANYNJ. Bearing in mind that there is a restriction on the arrival of trucks that have high emissions at that port, the regulating yard is obsolete. It is important to highlight the interdependence between the scheduling with time slots and the measures adopted at the Santos yard considering that both systems address operational and environmental aspects. However, in the ports of developed countries, strategies to reduce environmental impacts have a stronger effect because regulations can be strictly enforced by imposing fines, as is the case of the measures of success adopted by PANYNJ. The solutions adopted at those ports are assertive as they are linked to government policies, while in Brazil they had little effectiveness, considering the results of the attempts already made by the managers of the Port of Santos.

Access restriction to the primary area of Euro IV trucks or older, if adopted at the Port of Santos, would generate immediate results and would be an important environmental control strategy. This strategy is part of the scope of the CETESB, according to their managers, as a new proposal regarding access regulation in Santos, with control being carried out by means of a truck's RFID tag and the application of fines being assessed when a truck enters the port's secondary area. Environmental strategies are the most difficult ones to apply in the Port of Santos taking into consideration that CODESP has a limited jurisdiction over the maritime access channel and primary area. Action from the government has been delayed due to disagreements among several parties from the three government spheres. This has prevented the implementation of effective measures that would improve the environment and quality of life in the city since the municipal and state regulations cannot be enforced at ports in federal area. Therefore, as a result of the assertiveness of the strategies to organize the terrestrial port access in the environmental aspect, the prohibition of access to the primary area of Euro IV trucks or older may be classified as the most effective strategy. Considering their limitations and restrictions, regulating yards have a similar effectiveness, despite not having been built for this end. Both from environmental and from operational aspects, the most notable aspect is provided by the intensification of the port and city relation, strengthening the structures of shared management.

6. Final considerations

The increase in trade with other countries demands logistics structures that have a high operational yield. The use of new technologies to maximize the capacity to move cargo and rationalize transshipment operations has brought more efficiency to port systems. Regarding the organization of terrestrial traffic, each port has developed its own access control system based on its operational format, governance regulations, and environmental restrictions. In 2014, the Port of Santos adopted its own access control system under the responsibility of the Santos Port Authority. This research aimed to evaluate the logistical and environmental effectiveness of the organization method of terrestrial access adopted by the Port of Santos having as reference the solutions adopted by the ports of New York/New Jersey and Newark/Elizabeth.

The organization method of terrestrial access adopted in Santos proved to be an effective alternative from a logistics operation perspective with the implementation of the regulating yard. This measure was possible only due to the availability of supporting areas, which were not available at the ports of New York/New Jersey and Newark/Elizabeth. On the other hand, the limitation imposed on port governance by the legislation in force in Brazil hinders long-term planning and restricts investments that could be made by the private sector.

Regarding the environmental perspective, it was possible to conclude that the conditions of an emerging country strongly influence the approaches taken to address this issue. Cultural and economic barriers hamper the adoption of measures to reduce harmful emissions in Santos. Measures taken at the ports of New York/New Jersey and Newark/Elizabeth, such as the scheduling of access for trucks depending on the vessel's berth, the prohibition of access for older trucks and the programs for fleet renewal, would be difficult to implement at the Port of Santos. Operational restrictions and limitations in the investment capacity of freelance drivers and truckers are still predominant barriers.

Port terrestrial access will continue to be a contentious point in the relationship between ports and cities while multimodality is not encouraged. As a result of several interventions over the years, the Port of Santos currently has weak shared management after the change in the competencies in its Port Authority. This might be an obstacle to implementing long-term plans and thus creates an environment of uncertainty for the entities involved in the port's operation and management. Chart 4 summarizes the findings of this study.

6.1. Limitations and suggestions for future research

This study has limitations and restrictions. The economic aspects of installing a regulating yard as well as the fact that a loaded truck is a parked warehouse that consumes financial resources, such as shipping and stock in transit costs, have not been assessed. The lack of data on the movement of trucks does not allow the measurement of the waiting lines, only their occurrences. The data were corrected considering the length of the access road and traffic speed. The data from the air quality monitoring stations may not represent pollution from port activity only since they are located outside the port's primary area. Other studies that assess technological devices for the control of trucks' arrival and the monitoring of harmful emissions and the implementation of an access restriction for older trucks in the Port of Santos are still necessary.

Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.trd.2019.08.030.

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