Competitiveness throughout the seaport-hinterland: a container shipping analysis

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With customers looking for the highest level of services and reduction of cost on international trade of goods, shippers have recently begun to focus on the inland leg of containerized import/export, making the competition advance between ‘seaport against seaport’ to ‘seaport-hinterland against seaport-hinterland’. Bearing this in mind, this paper seeks to assess the logistic costs and the import process time in order to identify how these factors influence seaport-hinterland customer’s choice and what is the effect of these factors on the main actors’ competitiveness. In terms of time, the findings indicate that dry ports have been operationally more efficient, with customs and delivery process faster than in seaports and extended gates. In terms of cost we have applied Monte-Carlo simulation in a case study in Brazil to assess stochastically the import cost considering multiple actors as options. The study makes practical contributions, showing the cost efficient zone for each macro region in the studied area and simulating a hypothetical scenario, where multimodal transportation is a delivery option. Lastly, the study makes theoretical contributions, discussing the competitiveness environment in light of the literature, bringing relevant insights to aid customers’ and practitioners decision-making.

Keywords: seaport-hinterland network; cost model; customer’s choice; competition.

# 1. Introduction

The international trade of goods has intensified the demand for efficient logistic operations. With the economy of scale resulted from the maritime transport, which moves 90 per cent of international cargo trade, shippers/consignees have broken distances barriers and started to seek providers that fulfil better their expectations, enhancing the competitiveness throughout the world (Haralambides 2019). Despite this grown of maritime operations, some complexities emerge when customers expand their analysis from a ‘seaport to seaport’ to a ‘door to door’ perspective. In this context, particularly challenging are seaport-hinterland. This step is defined as all service/operation that take place from the customer facility until the containerized cargo be loaded in the vessel (from the export side) our since the container is discharged in the seaport yard until reach the customer facility (from the import side) (Fazi and Roodbergen 2018; Miraj et al. 2021).

Indeed, customers are looking for the entire supply-chain to optimize their operations, reducing the total logistic cost, ensuring reliability and avoiding shortages (Jeevan, Chen, and Cahoon 2019). Essentially, any failure or unreliability in a seaport-hinterland services results in unhappy customers as a consequence of the disruption in the smooth import/export process (Rodrigues et al. 2021a). As the competition in globalized markets forces organizations to focus on their core competencies and outsource other activities, the complexity of services required by the customers have opened opportunities for new actors in the supply-chain (Jeevan, Chen, and Cahoon 2019; Nguyen and Notteboom 2019). In this scenario, dry port emerged as option. It is defined as inland intermodal terminal directly connected to seaport(s) with high-capacity transport mean(s), where customers can leave/pick up their standardized units as if directly to a seaport (Roso, Woxenius, and Lumsden 2009). Another strategy used by seaports is extending the terminal gate to include selected hinterland locations, enabling the movement of containers into those locations without prior involvement of the shipping company, the shipper/receiver or customs (Veenstra, Zuidwijk, and Van Asperen 2012). These inland terminals managed by the seaports is called extended gate.

Despite multiple actors in seaport-hinterland enhance the competitiveness, such infrastructure makes complex the customers’ choice in select their services providers, requiring more deep analysis. Two key issues arising within the above literature are how customers’ select their service providers and how seaport-hinterland actors interact and compete within the same hinterland (intra competition) and among different ones (inter competition). Our present contribution to this literature will explore such competition by the customer seaport-hinterland choice through the view of ‘time’ and ‘cost’, two traditional logistic decision drivers (Jeevan, Chen, and Cahoon 2019; Khaslavskaya and Roso 2020).

Considering the complexity among seaport-hinterland actors/functions, the range of cost factors related to import/export process, as well the variable customs and process time affecting the seaport-hinterland, it is imperative to further explore these issues in order to aid customers to choose their logistic operators. With this in mind, our aim is to not only assess the costs evolved throughout the seaport-hinterland and the customs process time of each step (documental and operational), but also to understand the impact of these factors among the main actors discussing the competitiveness in light of the literature. Furthermore, simulating hypothetical scenarios of seaport-hinterland multimodal network may bring relevant insights to aid customers, investors and policy-maker in their decision-making. Thus, we stated our research question:

*RQ: How ‘cost’ and ‘time’ influence the seaport-hinterland customer’s choice and what is the effect of these factors on competitiveness.*

To address this research question, the rest of the paper is structured as follows. In section 2, we articulate the Brazilian context of our study and explain why it matters. In section 3, a review of previous literature on seaport-hinterland competitiveness is undertaken, stating the research hypothesis. In section 4, we address our study methodology and the formulation of the cost mode. The results are presented in section 5 and a discussion of these results is presented in section 6. The paper concludes in section 7 with theoretical and practical implications being elaborated.

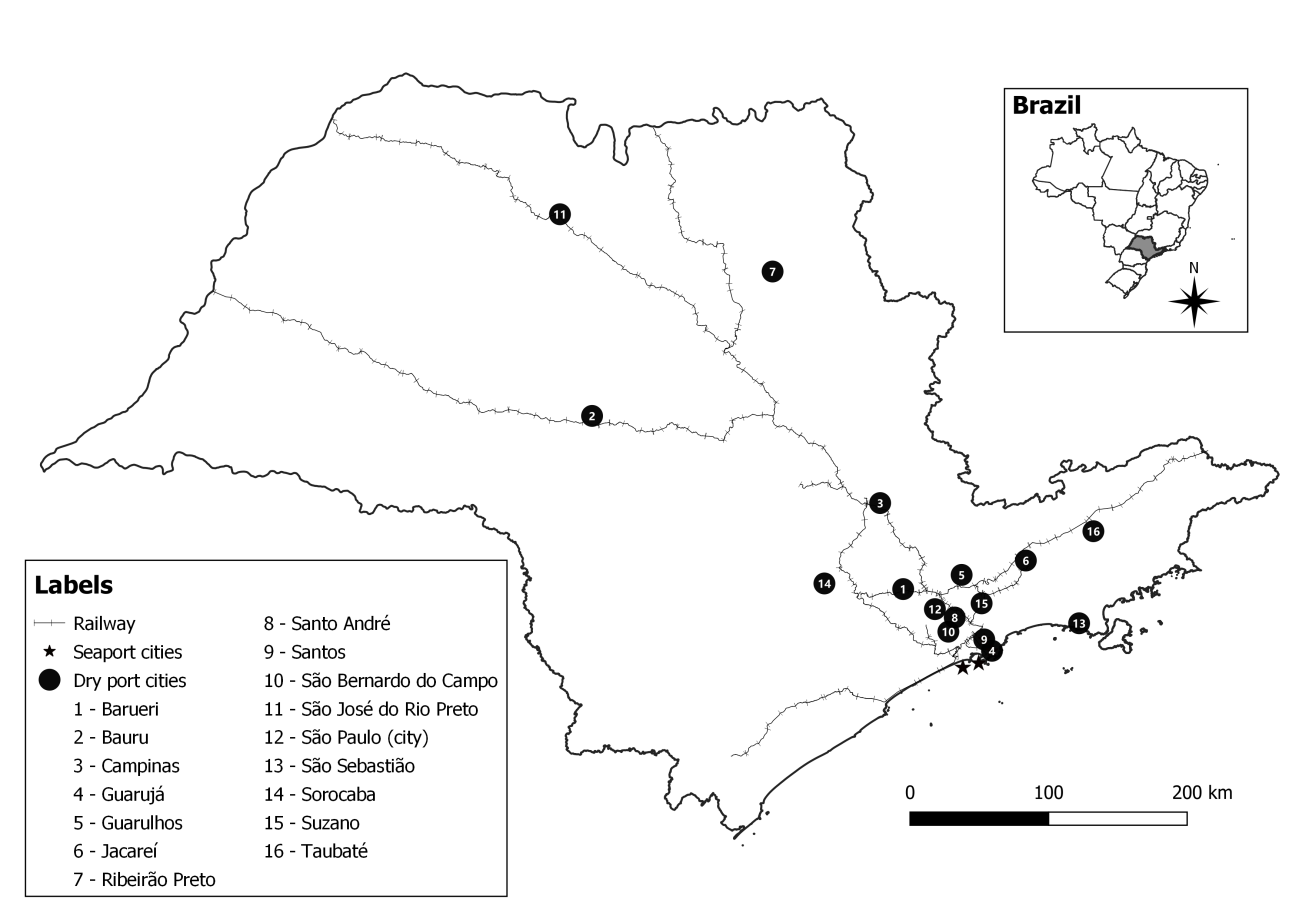
# 2. Study context

The present study focuses on logistics infrastructure in Brazil as case study, more specifically in State of São Paulo. Brazil is the 10th economy in the world, with a GDP of US$2.06 trillion (IMF 2022). Brazil is the 20th largest container-handling economy in the world, handling more than 10 million TEUs per year with the Santos seaport hub in São Paulo state being responsible for 34 per cent of this volume (ANTAQ 2021; UNCTAD 2019).

Within its hinterland, there are currently 56 dry ports in Brazil (Rodrigues et al. 2021a). The connection between seaports and hinterland in Brazil is dominated by road (65 per cent of the transport share). With 15 per cent participation in the transport matrix and focused on transport commodities as iron ore and grains (80 per cent of total volume), Brazil has a low density of rail network (ANTF 2019). In the Brazilian perspective, the seaport-hinterland refers to the connection of the land side of the country with the seaport. Regarding the ship of containerized cargo, this integration is made especially by road, with dry ports not been directly connected with the seaport. In this way, dry ports in Brazil fulfil a different role, when compared with developed countries, focusing on offering cheapest custom storage services, performing additional and personalized logistic solutions, reducing bureaucratic processes and the occupancy in seaports (Rodrigues et al. 2021a).

The State of São Paulo is the industrial and economical center of Brazil. São Paulo has approximately 46 million people living across 645 cities in 15 macro regions, with a GDP of US$ 603 billion, making it the 21st largest economies in the world and the third largest economy in South America (IBGE 2021). Exports from São Paulo amount to approximately US$51 billion while imports amounted to approximately US$59 billion in 2019. São Paulo has the largest airport (Guarulhos) and seaport (Santos seaport hub) in Latin America. In terms of hinterland infrastructure, São Paulo has 24 dry ports spread across 16 cities, as follows in Figure 1.

Figure 1. Seaport-hinterland network of São Paulo state



Although dry ports are described as inland intermodal terminals that are usually directly connected to seaport through high capacity transport modes such as railways, dry ports in São Paulo are not directly connected to seaports through railway. This makes it contestable whether there are any real benefits of dry port for customers in terms of cost. Furthermore, dry ports in Brazil face very bureaucratic customs processes, poor legislation (both in terms of availability and implementation), poor intermodal infrastructure and an unwarranted competition between seaports and dry ports (Rodrigues et al. 2021a).

# 3. Seaport-hinterland network choice and competition

Competitiveness is an aspirational attribute of operations because it enables firms to survive and thrive (De Oliveira and Cariou 2015). The competition in fact occurs based on the competitive priorities, which are goals and choices that reflect aspirational, conditional and preferential emphasis in the company’s strategy to select, develop and use competitive capabilities in reinforcing competitive advantage and satisfying customer and market demands (Durugbo et al. 2021). There are a range competitive priorities, or factors, that determine the choice behaviour of customers; the core dimensions described in the literature are cost, quality, time and flexibility (Durugbo et al. 2021).

In this context, the preference among different stakeholders for seaport-hinterland to operate through either a dry port or a seaport may involve numerous considerations. A review regarding the mains factors engaged in this choice found a set of 25 service level factors that should be considered for decision-making, including customs clearance efficiency, provision of on-time and accurate information, responsiveness, operational reliability, safety and security in transportation. Focusing on dry port choice, Onwuegbuchunam and Ekwenna (2008) found that the service level, security, efficiency, infrastructure and proximity to market are the most important factors influencing the choice of dry ports by shippers. From the hinterland side, a number of studies have found that factors such as total logistics cost, responsiveness, satisfaction with previous service, reputation of the logistics operator, intermodal connectivity, and speed are the most important factors engaged in choice the logistic operator (Rezaei et al. 2019).

Integrating the same supply-chain, dry ports, extended gates and seaports may build a competitive cargo shipping environment, depending on the objectives and the relationship among various stakeholders (actors) (Nguyen and Notteboom 2019). The literature reinforces the notion that the efficiency of supply chains may be impacted by conflicting objectives among stakeholders. For example, (i) while shipping lines design their service network in a manner that makes most of the scale economies, (ii) the aim of freight forwarders is to provide value-added services to their final customers, (iii) seaports and dry ports seek to maximize their hinterland chain throughputs, while (iv) intermodal carriers generally focus on maximizing their hinterland chain profits while (v) importers and exporters focus on minimizing the hinterland chain logistics costs of their cargoes (Talley and Ng 2017).

Competition within the cargo shipping environment may also exist within steps that are carried out during the import/export process. First there is intra competition, which is the competition inside the same seaport-hinterland network, concerning the competition (i) among dry ports in the hinterland, (ii) among seaports, (iii) between dry ports and seaports, and (iv) between road and rail carriers (Garcia-Alonso, Monios, and Vallejo-Pinto 2017). Second exist the inter competition, concerning the competition among different seaport-hinterland networks, which may happen in the same country (between states) or between countries (De Oliveira and Cariou 2015). The intra competition may be expressed as the example of seaports and dry ports competing to store the container cargo, which happens mainly when the throughput of containers in the seaport is low, having yard capacity to store containers available (Rodrigues et al. 2020). Going beyond, an example of inter competition between countries or seaport-hinterlands will exist where different ones offers tax benefits to attract the import/export service (Cheon, Song, and Park 2018).

With increased competition in the global market, companies are required to be efficient not only within their organization but throughout their supply chains (Jeevan, Chen, and Cahoon 2019). Empirical studies on seaports in the United States find evidences that the competition between seaport-hinterland actors is associated with high efficiency, since it provides incentives for companies to improve their operation (De Oliveira and Cariou 2015). With this in mind, while importer/exporters are looking to reduce their logistic cost, the actors in the seaport-hinterland network struggle to improve their services to first gain the intra competition and enlarge their actuation zone.

It was observed in the literature that the sole efforts to improve service quality or reduce the logistic cost by an unique actor in the supply chain looks ineffective and, despite the challenging task due the interest conflicts of different stakeholders, higher integration and coordination between the players in supply chains lead to a higher competitiveness of the entire hinterland (Ha and Ahn 2017). It was confirmed also in China by Li et al. (2022) demonstrating that dry port logistics supply chain integration has a positive effect on logistics cost performance and service quality performance, which further improves dry port competitiveness. With that in mind, we stated the following hypothesis to better understand the competitiveness among the main actors in seaport-hinterland network in terms of cost and time.

## 3.1 Hypothesis propositions

A dry port can serve as an inland clearance depot which may greatly improve customs clearance efficiency of multimodal transport, reducing the congestion in seaports (Rodrigues et al. 2021b). Customs clearance were perceived as one of the most important factors for Malaysian dry port stakeholders (Jeevan, Chen, and Cahoon 2019). Reinforcing that, Jiang et al. (2020) identified that customs clearance time have significant impact on shippers hinterland transport chain choice behaviour. With that in mind, considering the lower volume of customs process in dry ports, we stated the first hypothesis.

* Hypothesis 1. There are differences in customs clearance process time among seaports, dry ports and extended gates.

In order to avoid low operations efficiency, a seaport only provides a temporary storage space for containers by charging storage fees if containers’ dwell time is longer than a free-time-limit. A dry port, however, usually charges a lower storage fee than that charged by the seaport container yard (Rodrigues et al. 2020). Hence, the customers takes more time operating through dry port, since it is more attractive for relatively long-term storage in terms of cost (Qiu, Lam, and Huang 2015). In order to test this literature in the Brazilian case, we defined the second, third and fourth hypothesis.

* Hypothesis 2. There are differences in the time to begin the customs process among seaports, dry ports and extended gates.
* Hypothesis 3. There are differences in the time to remove the container from the seaports, dry ports and extended gates.
* Hypothesis 4. There are differences in the total import process time among seaports, dry ports and extended gates.

Considering that the portion of inland costs in the total costs of container shipping would range from 40 to 80 per cent, and it could be reduced by one third with appropriate regionalization strategies, the interest of shippers and consignees about the hinterland transport chain has been increased (Notteboom and Rodrigue 2005). In this context, dry ports has emerged as an option that could bring significant benefits to stakeholders involved in hinterland transport operations by improving distribution systems and reducing direct and indirect logistics costs (Khaslavskaya and Roso 2020). In order to test the shipping cost efficiency using dry ports, we stated the fifth hypothesis.

* Hypothesis 5. Shipping cost could be reduced by using dry ports as logistic operator.

The seaport-hinterland network should be connected efficiently to ensure reliability and reduce the transportation cost through scale economy, making dry ports attractive to shippers and consignees (Garcia-Alonso, Monios, and Vallejo-Pinto 2017; Jeevan, Chen, and Cahoon 2019). The transportation mode in this study refers specifically to the seaport-hinterland network, and it may occur by unimodal transportation (roadway) between the customers and the seaport/dry port, or by multimodal transportation, using a combination of two or more modes of transportation (roadway, railway or waterway) connecting dry ports/extended gates with the seaports (Khaslavskaya and Roso 2020).

Some issues emerge concerning the real economy of scale for customers using dry ports when they are not direct connected with the seaport, as the case of Brazil (Rodrigues et al. 2021a). By contrast, despite Brazil be a continental country, the main industrial and consumption zone, located in São Paulo state, are near to the seaport, such as happen in the Republic of Korea and those of Southeast Asia countries, with distances between trade origins or destinations ranging of 100-300 km, putting in check the advantage of scale economy of multimodal transport (UNESCAP 2015). Going beyond to this issue, we simulated a hypothetical scenario where the studied dry ports were direct connected with the seaport through railway, comparing the results with the current context and testing the sixth hypothesis.

* Hypothesis 6. Dry ports directly connected through multimodal transport with seaport are cost efficient.

# 4. Methodology

In order to test the hypothesis regarding the competitiveness in terms of ‘time’, it were compared statistically the import process through seaports, dry ports and extended gates based on historical data. In terms of ‘cost’, we have developed a cost model approach to assess the import cost since vessel berthing until the container cargo reaches the customers’ door. Then, we simulated the cost model stochastically through Monte Carlo method in a case study in Brazil, following Jung et al. (2020). As dry ports in Brazil are characterized to operates mostly import cargo, enabling the analysis, the case study is limited to the import process (Rodrigues et al. 2021a). With that in mind, the next topics describe the methodology and the cost model proposed.

## 4.1 Step 1 – Import process description

The import process of containerized cargo may be simplified in 4 steps (Fazi and Roodbergen 2018). The ‘Step 1’ is the time between the vessel berthing and the cargo manifest, when the seaport declares that the container is located on the yard. As for dry ports the cargo should be transported from the seaport by road or multimodal transportation under customs control, ‘Step 1’ is broken in ‘Step 1.1’ for the time between the vessel berthing and the Declaration of Customs Transit (DTA), when the container is released to be delivered to dry port, and ‘Step 1.2’ for the time between the DTA and the cargo manifest already in the dry port. Then, ‘Step 2’ is the time between the cargo manifest in the seaport/dry port and the import declaration record, when the customer/consignee formalizes the cargo information for the customs authority and begins the import clearance process.

Step 3 is effectively the clearance process time where the cargo is parameterized in three different channels: (i) green channel, whereby the clearance of the cargo occurs automatically; (ii) yellow channel, when the clearance of the cargo requires a documentary examination; and (iii) red channel, whereby the cargo is only cleared after the documentary examination and physical inspection. After that, the ‘Step 4’ is time between the goods is nationalized and delivered for the customer. Aggregating the above steps, we define as ‘Full Process’ all the time expended since the vessel berthing until the cargo leave the seaport/dry port facility. The import process for extended gate is stated as the same of seaports.

## 4.2 Step 2 – Data and tools

We got data of the customs clearance movement and times from the database of Brazilian Federal Revenue (BFR 2021). The database aggregates the process time of containerized import of goods through all logistics operators in São Paulo state in the year 2019, parameterized in the three different customs channels. After clean the missing values, a total of 23,099 imports register through seaports, 8,602 through dry ports and 8,305 through extended gates were considered for the statistical analysis and for the Monte Carlo simulation.

The parameters were obtained from multiple sources. Related to road cost, we obtained data from the National Association of Cargo Transport and Logistics (NTC 2021), from resolution 5.867 of National Agency of Ground Transport (ANTT 2021) and from the study of Araújo, Bandeira and Campos (2014). The rail fees were based on the average charged by the 2 rail carriers operating transport containers in São Paulo state. Dry ports fees were based on the services average charges of 7 companies responsible for the management of 11 dry ports in São Paulo; these were the dry ports that provided the service tariff table after our request. In the same way, we considered the average rate of the 3 most important container terminals located in the Santos seaport and 6 line operators/ship-owners. The road distances considered in the model was assessed by Google Maps, the simulations and statistical analysis were coded in Python 3.8.5, using especially Pandas, Numpy, Statistics, Scipy and Fitter libraries. Lastly, to display the results in a map format, we used QGIS 3.16.

## 4.3 Step 3 - Statistical results and analysis

Step 3 starts the data analysis, answering hypothesis 1 to 4. First, a descriptive analysis was performed to identify the mean, median, and standard deviation of the sample. Second, the outliers of the dataset were dropped considering 3 standard deviations as reference. To define which statistical test apply to compare the import process time among the logistic operators, a Shapiro-Wilk test was run, confirming that no sample in any step of the process followed a normal distribution (rejecting the null hypothesis), requiring a non-parametric test for the sample comparisons. In this way, the Mann-Whitney tests (‘U’ test) were paired performed to identify if there are statistical differences of import process time among seaport, dry port and extended gate. The significance level for all tests was 0.05 in the bi-tailed tests.

## 4.4 Step 4 – Cost model simulation

For the cost simulations, we have concentrated on the current seaport-hinterland network of São Paulo state. It were considered 4 dry ports’ locations as options for the simulations based on the dry port classification (Roso, Woxenius, and Lumsden 2009): Santos dry port/extended gate, 10 km far from the seaport (close); Campinas dry port, 163 km far from the seaport (midrange); São José do Rio Preto (SJRP) dry port, 518 km far from the seaport (long distance); and São Paulo dry port, located in the capital of the state, 72 km far from the seaport (close). The seaport city is Santos and the transportation mode is the road, since there is no dry port directly connected with the seaport in São Paulo state. The simulations were divided in two parts: (i) according to the current seaport-hinterland in São Paulo state, comparing the import cost for each actor; (ii), according to a hypothetical scenario, estimating the cost impact for the customers if dry ports were directly connected with the seaport through railway.

For the Monte-Carlo simulations, we focused on the data distribution of import cargo through dry ports. The objective here was identifying if the customers that are using dry ports in Brazil are making the cost efficient option and what is the inflection point of import process time when dry ports becomes more cost competitive. The stochastic variables in the cost model were fitted through the Fitter library in Python, testing 80 possible distributions and selecting the one that best fitted based on the Sum Square Error (SSE), Akaike Information Criterion (AIC), Bayesian Information Criterion (BIC), and Kullback–Leibler divergence (Kl\_div) (Martínez-Pardo, Orro, and Garcia-Alonso 2020). For the Monte Carlo simulation, we got the distribution parameters for ‘Full process’ time, ‘Step 1’ time for dry ports (aggregating steps 1.1 and 1.2 of import process), and for the ‘cargo value’ , considering 62,255 containerized import cargos registers in São Paulo state in the year 2019 (Economy Minister 2021). The results of goodness of fit, the best distribution and the respective parameters used for the cost model simulation follow in Table 1.

Table 1. Goodness of fit and distributions parameters

## 4.5 Cost model

The cost model was built based on previous researches that contributed to our understanding of the seaport-hinterland network (Iannone and Thore 2010; Tran, Haasis, and Buer 2017; Qiu and Lam 2018). A literature review of the main cost factors also follows in Rodrigues et al. (2020). With this in mind, the total logistics cost () is assessed aggregating the handling cost (), storage cost (), customs cost (), inventory cost (), demurrage and detention cost (), and the transportation cost to delivery () and return the empty container () as follows.

Where:

The variables and parameters of the model follow in Table 2.

Table 2. Variables and parameters of the model

# 5. Results

## 5.1 In terms of time

The first outcome was the descriptive analysis for each step of the import process through seaport, dry port and extended gate. The results for ‘step 3’ and ‘full process’ were divided in green channel (GC) and yellow/red channels (YRC) and follows in Table 3. Some discrepancies of the import process time among the actors are highlighted in grey. First, the mean and median time of the full process for GC and YRC presented a higher value in dry ports, mainly due the time expended in ‘step 2’. Second, the customs process for GC and YRC in ‘step 3’ highlighted the difference of the process time when the cargo should be documental or physically inspected. Lastly, the process time for step 1 is notably higher for dry ports, since the cargo should be liberated in the seaport (step 1.1) and then transported under customs control (step 1.2).

Table 3. Process time in days of each step for import cargo

In order to test the hypothesis 1 and identify if there are differences in the customs process time among the main logistic players, we ran a Mann-Whitney U test in the samples of GC and YRC. The results that follows in Table 4 shows that there is no statistical evidence that the customs clearance process time (step 3) for the seaport, dry port and extended gate follows the same distribution, rejecting the null hypothesis. For the green channel, the median time for seaport (0.302 day), dry port (0.267 day) and extended gate (0.325 day) shows that the process time for dry port is faster. Operationally, the customs process in green channel in all logistic operators occurs in the same day. However, for yellow/red channels, the median customs process time in dry ports (3.141 days) is considerable faster compared to seaport (8.945 days) and extended gate (7.872).

* Answering Hypothesis 1: The result confirms that there are differences in customs clearance process time among seaports, dry ports, and extended gates.

Table 4. Statistic test for the import process

Answering the hypothesis 2, the results from the Mann-Whitney U test for ‘step 2’ shows that there is no statistical evidence that the time to begin the customs process is the same for seaport, dry port and extended gate, confirming the hypothesis 2. The median time for step 2 were 2.056 days for seaport, 11.897 days for dry port, and 2.822 days for extended gate, which means that customers takes more time to begin the customs process in dry ports.

* Answering Hypothesis 2: The result confirms that there are differences in the time to begin the customs process among seaport, dry port, and extended gate.

For answer the hypothesis 3, the Mann-Whitney U test ran comparing dry port with seaport and extended gate for step 4. The results show that there is no statistical evidence that they follow the same distribution. However, the comparison between seaport and extended gate resulted in a p>0.05, failing to reject the null hypothesis. Considering this output, as the median time for step 4 in dry ports (1.838 days) is fewer than in seaport (2.299 days) and extended gate (2.232 days), the data reveals that the customers take more time to remove the container from the seaport and extended gates.

* Answering Hypothesis 3: the result confirms that there are differences in the time to remove the container from dry ports compared to seaports and extended gates. However, there is no statistical evidence that there are differences in the time to remove the container between seaports and extended gates.

The last analysis in terms of time looked for the entire import process, answering the hypothesis 4. We divided the sample in (i) green channel and (ii) yellow/red channels. The Mann-Whitney U test rejected the null hypothesis for all comparisons in green channel, resulting that the import process for all logistic operators follows different distributions. On the other hand, for yellow/red channels, the test between seaport and extended gate failed to reject the null hypothesis, having insufficient evidence to conclude that the difference between medians is statistically significant. The data in Table 3 shows that the median time of the full process in dry ports for sample GC and YRC were 27.79 and 26.20 days respectively. This value is considerable higher compared to seaport (7.26 and 16.11 days) and extended gate (8.30 and 15.83 days), confirming the hypothesis 4. Going beyond this result, the difference between the full process time in dry ports for GC and YRC is not considerable, demonstrating that the cargo stays in the dry port for a longer time due a customer requirement, not because the customs process. On the other hand, the full process time in seaport and extended gate for green and yellow/red channels presented a high difference, especially due the customs process.

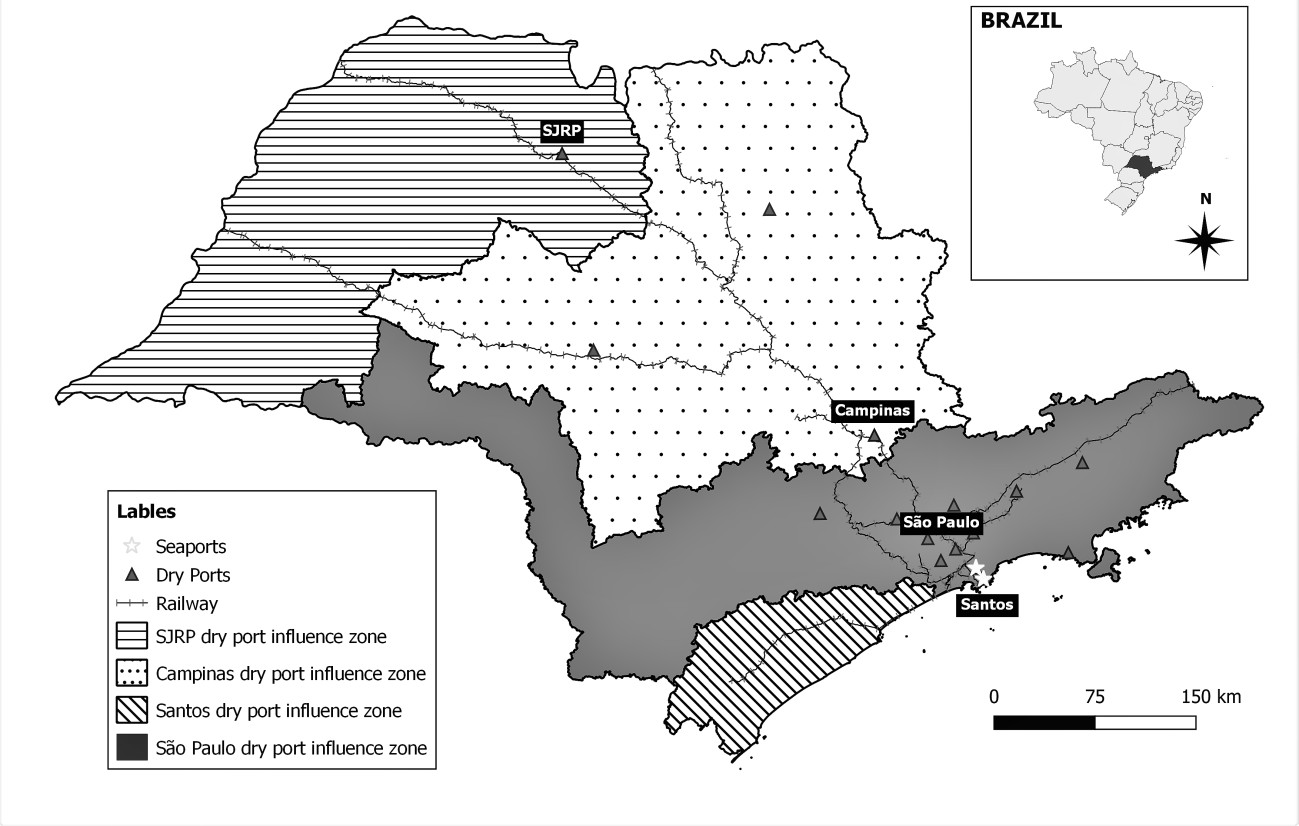
* Answering Hypothesis 4: the result confirms that there are differences in total import process time for green channel among seaports, dry ports and extended gates, and for yellow/red channels between dry ports and seaports/extended gates. However, there is no statistical evidence that there are differences in total import process time for yellow/red channels between seaports and extended gates.

## 5.2 In terms of cost

The cost for import a containerized cargo varies stochastically according to many factors as the cargo value, the storage time, delivery distances and others that were aggregated in the cost model proposed. To compare the import cost through dry port and seaport we used the full process time distribution fitted from the database for the dry port users, considering that if the customer wants their cargo as soon as possible, they will remove the cargo directly from the seaport. Doing that, we simulated the import process varying the cargo value and the import process time according to the distributions parameters stated before, and using the current logistic transportation infrastructure in Brazil (road transportation by truck).

We first assessed the cost efficient dry port facility for each macro region of São Paulo, finding the influence zone of each dry port as follows in Figure 2. Campinas dry port was the cost efficient facility for most macro regions (6); SJRP serves the macro regions far from Santos seaport, while the most populated and industrial zone of São Paulo is best served by dry ports located in São Paulo city macro region. Since the cost parameters for the dry ports (operational costs) were considered the same, the results vary according to the delivery and return distance of the container.

Figure 2. Influence zone of dry ports in São Paulo state

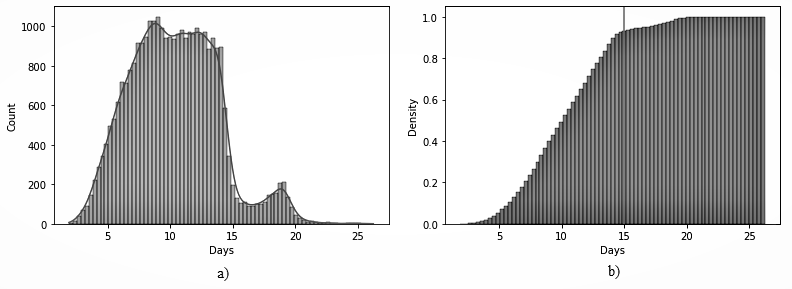


The statistical results that follow in Table 5 show the difference between the cost to import through seaport and the cheaper dry port for each macro region. Some highlights from this results is the fact that the mean and median difference cost for all cities are positive, which means that for customers that are importing containerized cargo with the characteristic of dry port’s users (in terms of process time) are mostly choosing the cheaper option. However, as the minimum values from the simulations were negative, for some cases, seaport seams the best option in terms of cost. Taking into account the outputs of the simulation, the last column of Table 5 (column ‘P’) assess the probability of a containerized cargo that follows the process time of dry ports be cost efficient using seaport compared to dry port. This result shows that for around 22 per cent of the simulations seaport was cheaper than dry ports.

Table 5. Cost difference between seaport and the best dry port option

Considering that for some cases the import process through seaport were cost efficient, it’s relevant to identify the inflection point in the full import process time that makes dry port more attractive, answering the hypothesis 5. With this in mind, all simulations where seaport was cost efficient for all cities were aggregated in the histogram in Figure 3(a). As the distributions for the Monte Carlo simulation represented the import time based on dry port users, few evidences with a short import process time (less than 10 days) ran in the simulations, and all results had seaport as the cheaper option. The Figure 3(b) shows the probability density function of the evidences of seaport been cost efficient varying in function of the import process time. The results show that 93 per cent of the cases where seaports were cost efficient were for import process time less than 15 days. In this way, we stated 15 days of import process as the inflection point where dry ports becomes cost efficient, confirming that import through dry ports is cheaper for a long storage time.

Figure 3. Evidences and density function per day of import process



* Answering Hypothesis 5: Shipping cost could be reduced by using dry port as logistic operator for a long storage time (higher than 15 days).

Going beyond the inflection point to measure the opportunity for dry port managers to enlarging their market share, competing in terms of cost, we have assessed the quantity of cases in the seaport users’ database of year 2019 where the import process took more than 15 days. The results have shown that 13.76 per cent (3125 cases) of the cases surpassed 15 days for green channel and 57.27 per cent for yellow/red channels (189 cases), which demonstrate a great opportunity for dry ports to enlarge their market share, especially regarding the cargo that goes to physical inspection. Doing the same with the dry port users’ database, we observed that the opportunity for seaport to keep the cargo in their facility is proportionally higher for green channel, where 26.22 per cent of the containerized cargo took less than 15 for the full import process using dry ports (2151 cases). For yellow/red channels, 14.28 per cent of the import cargo through dry ports took less than 15 days (57 cases), meaning that seaport should be a cost efficient option for those cases.

So far, the simulations have tested the import cost based on the current seaport-hinterland of São Paulo state, where there is no dry port directed connected with the seaport through multimodal transport. In order to identify if dry ports directly connected with seaports through railway would reduce logistic cost for the customers, we simulated and compared this hypothetical scenario with the current one, keeping the other parameters as stated before. First we compared the cost results from both scenarios through a Mann-Whitney U test, confirming that there is no statistical evidence that the cost by rail and by road using dry ports follows the same distribution (rejected null hypothesis). The median cost for all logistics operators had cheaper costs for the hypothetical scenario, confirming the hypothesis 6 that dry ports directly connected through multimodal transport with seaport are cost efficient. A synthesis of the total logistic cost for each logistic operator, aggregating the results for all cities considered in this study follows in Table 6.

Table 6. Import cost using road and rail transportation for all logistic operators

* Answering Hypothesis 6: Dry ports directly connected through multimodal transport with seaport are cost efficient.

Lastly, despite the transportation through railway be cheaper compared to road, the real relevance of that difference should be considered by the customer. The median cost differences from rail to road were $112.5, $50.5, $46.9 and $34.6 for SJRP, Campinas, São Paulo and Santos dry ports respectively. This result also means that the transportation cost reduces as the distance from the seaport increase.

# 6. Discussion

In this study, we deeply investigated how cost and time influence the choices of seaport-hinterland customers in selecting their service providers and the effects of these factors on competitiveness. To achieve the stated objectives, we first tested hypotheses related to the import process time by outlining the current context of customs processes in Brazil. To assess the cost of importing containerized cargo, we simulated different scenarios in the state of São Paulo using a cost model. This resulted in a map indicating the influence zone of cost-efficient dry ports and the inflection point of import process time at which dry ports become a more affordable option. Lastly, we simulated a hypothetical scenario to evaluate the impact on import costs for shippers if the dry ports in São Paulo were directly connected to the seaport by railway.

In seaport-hinterland network, seaports take advantage as the only player indispensable to import/export of goods, responsible for the vessel operation. As essentially customers requires their goods as fast as possible, especially regarding maritime transportation where the transport takes in some cases months, the majority of customers will begin the custom process and remove the container cargo directly from the seaport. Furthermore, import through dry ports or extended gate seems add another player into the supply chain, which may enhance the complexity. Despite these competitive advantages of seaports, customers are even more requiring personalized services and looking for reduce the entire logistic cost, services which in some cases, seaports cannot fulfil. Such issues enhance the competitiveness among the actors in the supply-chain and make more complex for customers to choice the logistic operator that best fit their requirements.

The first outcome confirmed that the customs process is faster in dry ports. As the cargo nationalization in green channel take place automatically by the Federal Revenue system, this process occurs in less than one day for all actors and do not impact the customers operationally. However, when the cargo is classified in yellow/red channels, it takes considerable much time in seaports and extended gate. One reason for that is the high volume of process in the seaport zone, which bring operational issues for positioning the container to physical inspection, requiring adequate infrastructure. The congestion problem in seaports also impacts other steps of the import process and the second outcome shows that since the cargo is already nationalized, the customers take more time to remove the cargo from the seaport and extended gate. It can happen due customer’s will, or again due congestion issues, where customers face difficulties to schedule the removal of the cargo especially due gate availability (Garcia-Alonso, Monios, and Vallejo-Pinto 2017; Jeevan, Chen, and Cahoon 2019). These issues affect the competitiveness of seaports and should be considered by customers when deciding which logistic operator choice.

The results from hypothesis 2, 3, and 4 show that the import process is longer for customers that use dry ports as logistic operator. Taking into account the seaport-hinterland decision, customers that choice dry ports are distinguished for not require their cargo as soon as possible. It may happens when they not have specialized infrastructure to handle and store container or when the importers are willing to pay for additional services, stock of goods and predictability/availability of their cargo. Besides the long time to import goods through maritime transportation, recent events have touched the relevance of predictability and supply chains disruption as the Covid-19 pandemic and the blockade of the Suez’ channel in Egypt in 2021, which brought import/export instabilities and shortages around the world (UNCTAD 2021).

According to the above context, dry ports gain competitive advantage in Brazil for three main reasons: (i) the cargo can stay stored for 120 days, compared to 90 days in seaport; (ii) dry ports works in a modality of ‘customs warehouse’, where the cargo is stored under customs control without require the immediate collection of taxes levied on importation; (iii) dry ports permits the partial removal of the goods, with the payment of import taxes only on the part to be cleared (Rodrigues et al. 2021a). Lastly, the results reinforced the relevance of dry ports in synchronizing the import cargoes with the customers’ production lines due the geographic proximity. This fact influences the competitiveness of dry ports, enhancing the customers’ reliability and avoiding supply chain disruptions.

In addition to competitiveness in terms of time, customers are struggling to reduce the total logistic cost choosing the best strategy in the seaport-hinterland network. The results have confirmed the competitive advanced of seaport as the cost efficient option for a short storage time in the hinterland, while dry ports works better for a long storage time. Simplifying the analysis and offering to the decision-maker a general insight, we stated 15 days since the vessel berth and the customer receive their cargo as the inflection point, when after that, dry ports starts to become the cheapest option. Analyzing the database from year 2019, we observed opportunities for enlarge the market-share for both sides, which is relevant for managers to gain the intra competition. As the fees charged may vary by contracts, dry ports and seaports managers’ should consider the import cost through all seaport-hinterland network in order to be more competitive.

Looking from the hypothetical scenario, the results revealed that dry port direct connected with seaport through railway would be cost efficient for customers. However, this competitive advantage is operationally small, compared with the total logistic cost. As the cost benefit using railways is low, customers should compare the cost-benefit taking into account other factors as the rail schedules and the transport time. Lastly, the simulations have shown that the effectiveness of multimodal transport improve as the distance. However, despite Brazil been a continental country, the industrial zone remains near the coast, as the case of São Paulo’s capital, located less than 100 km far from the seaport. This fact justify that in Brazil the rail transportation is dedicated to transport commodities as iron ore and grains, representing 80 per cent of total volume transported by rail, once the productive zones are located far from the seaports, in the middle of the country (ANTF 2019).

As stated in the literature, choice the logistic operator in seaport-hinterland network is a complex decision and the objective of this research was bring useful insights for customers to balance cost and time criteria as a first step in their decisions. Furthermore, the results have shown how dry ports and seaports managers may act in order to become more competitive and in which situation each logistic operator fulfils better the customers’ requirements, which may assist seaport and dry port managers in developing commercial strategies and defining the services offered.

Despite the competitive environment among the actors in the same area, the intra competition may strengthen the seaport-hinterland network, enlarging the influence zone of the seaport (inter competition) (Jeevan, Chen, and Cahoon 2019). As presented in the case of São Paulo, a well-structured seaport-hinterland network with multimodal transportation infrastructure and service capabilities strengthens the supply-chain and can stimulate new companies to establish themselves in the area. This can lead to an increase in cargo volume, which in turn may result in cost reduction through economies of scale.

Lastly, as an option to reinforce the seaport-hinterland network, we encourage the collaboration among the stakeholders in order to enhance seaports’ competitiveness, especially through information and risk sharing, improving the reliability and, coordination of the operations. This may be achieved by implementing a Port Community System, as in the case of Valencia seaport (Spain), covering the information from various stakeholders, particularly shippers, rail operators and seaports, producing integration and coordination between dry ports and their clients (Jeevan, Chen, and Lee 2015).

# 7. Conclusion

This study focused on customers’ choice on selecting the logistic operator that best serves their requirements in terms of time and cost to carry on the containerized import of goods. The results from the real case of Brazil have brought useful practical contributions for improve the competitiveness of the supply-chain as well contributed with the current literature of supply-chain choice.

As managerial contributions, our study attests that seaports remain as the most competitive player in seaport-hinterland. However, we identified that dry ports also fulfil an important role, becoming more competitive when the import process takes more than 15 days. The results from the Monte-Carlo simulations brought insights for customers’, aiding to choice the logistic operator and the delivery route with less information, as well for dry ports and seaports managers, highlighting the market-share opportunity and the strategic role that each logistic operator should exert. We would also suggest that multimodal transportation remains an option to reduce costs and optimize the seaport-hinterland network. However, the benefits should be investigated from multiple criteria, since the real benefits in terms of cost for customers are relatively low.

As practical contributions, our study offers relevant insights for multiple stakeholders in seaport-hinterland network. First, shippers can benefit from the results making better decisions in terms of time and cost in the container shipping process. Second, dry port managers may design strategies to enlarge their market share and improve the operational services in order to become more competitive. Third, the results may encourage investors in carrying new logistic infrastructures projects, taking market opportunities in the Brazilian case. Lastly, policy-makers may drive decisions to boost the multimodal transportation in Brazil, reducing the CO2 emissions and congestions, as well revising and improving customs process, making the seaport-hinterland network more efficient.

In narrower terms of our more academic-theoretical contribution, our study strengthened the discussion about seaport-hinterland network choice and competitiveness, testing 6 hypothesis based on previous literature for the Brazilian case, looking specifically for the inland side since the container is discharged until reach the customers’ door.

Some limitations were the focus on the assessable cost parameters stated in the literature, not considering specificities of logistic operators as the set of available additional services in each dry port/seaport as well the current taxes and operational charges of each actor in the studied hinterland. Moreover, the analysis focused on quantitative factors, remaining as opportunity for future researches to add qualitative factors as the service level, quality and flexibility perceived by the decision-maker, improving the decision model. Accordingly, for future research we suggest studies applying the proposed cost model in other environments as well using it as input for multi-criteria decision analysis. Lastly, studies using game-theory may strengthen the discussion about intra competition and inter competition on seaport-hinterland, enriching the agenda on international trade of goods competitiveness.

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