https://doi.org/10.47456/bjpe.v9i2.40525

Núcleo de Pesquisa em Gestão de Sistemas de Produção - NP GSP
Brazilian Journal of Production Engineering
BJPE - Revista Brasileira de Engenharia de Produção
Disponível em: https://periodicos.ufes.br/bjpe
ISSN: 2447-5580
UFES Campus São Mateus UNIVERSIDADE FEDERAL DO ESPÍRITO SANTO
UFES Pró-Reitoria de Pesquisa e Pós-Graduação Universidade Federal do Espírito Santo

ARTIGO ORIGINAL OPEN ACCESS

SORTING OPERATIONAL INDICATORS OF CONTAINER TERMINALS

ORDENANDO INDICADORES OPERACIONAIS DE TERMINAIS DE CONTÊINER

CLASIFICACIÓN DE INDICADORES OPERATIVOS DE TERMINALES DE CONTENEDORES

Thiago de Almeida Rodrigues [1*], Brenda Siqueira da Silva [2], Brunela Louvem Brunetti [3], & Julia Barbosa Pizzo [4]

[1 2 3 4] Universidade Federal do Espírito Santo, Centro Tecnológico

[1*] thiago.a.rodrigues@ufes.br [2] brenda.silva.45@edu.ufes.br [3] brunela.brunetti@edu.ufes.br [4] julia.pizzo@edu.ufes.br

ARTICLE INFO.

Received: 03.16.2023
Approved: 04.18.2023
Available: 21.04.2023

KEYWORDS: seaport; operational indicator; AHP.
PALAVRAS-CHAVE: porto; indicadores operacionais; AHP.
PALABRAS CLAVE: *puerto; indicadores operativos; AHP.*

*** Corresponding Author**: **Rodrigues, T. de A.**

ABSTRACT

Seaports are well known as playing an important role in multimodal transport systems and international supply chains, requiring operational efficiency to deliver value for the customers. In order to ensure a high-level service, managing an organization based on performance indicators are essential for drive the operations toward the strategic plan. Container terminals are inserted in this context, where the management effort and financial resources should be balanced in order to achieve the best utility of the entire system. With that in mind, this research aims to establish the dimensions of the most relevant operational indicators of Brazilian container terminals by applying the Analytic Hierarchy Process (AHP) multi-criteria method, providing a set of indicators as reference for decision-makers. Toward this goal, we carried out a systematic review in Scopus databases, identifying 38 dimensions of operational indicators that were pairwise compared by managers that represented 7 Brazilian container terminals, responsible for handling 71% of Brazil's container throughput. This research has made practical and managerial contributions, ranking the operational indicators to aid decision-makers to manage container terminals toward their strategy.

RESUMO

Os portos são conhecidos por desempenharem um papel importante em sistemas de transporte multimodal e cadeias de suprimentos internacionais, exigindo eficiência operacional para fornecer valor aos clientes. A fim de garantir um serviço de alto nível, gerenciar uma organização com base em indicadores de desempenho é essencial para direcionar as operações ao plano estratégico. Terminais de contêineres estão inseridos nesse contexto, onde o esforço de gestão e os recursos financeiros devem ser equilibrados para alcançar a melhor utilidade de todo o sistema. Com isso em mente, esta pesquisa tem como objetivo estabelecer as dimensões dos indicadores operacionais mais relevantes dos terminais de contêineres brasileiros, aplicando o método multicritério Analytic Hierarchy Process (AHP), fornecendo um conjunto de indicadores como referência para os tomadores de decisão. Para alcançar esse objetivo, realizamos uma revisão sistemática nas bases de dados Scopus, identificando 38 indicadores operacionais que foram comparados em pares por gerentes que representam 7 terminais de contêineres brasileiros, responsáveis pelo movimentar 71% do volume total de contêineres do Brasil. Esta pesquisa tem contribuições práticas e teóricas, classificando os indicadores operacionais para ajudar os tomadores de decisão a gerenciar terminais de contêineres em direção à sua estratégia.

RESUMEN

Los puertos marítimos son bien conocidos por desempeñar un papel importante en los sistemas de transporte multimodal y las cadenas de suministro internacionales, requiriendo eficiencia operativa para ofrecer valor a los clientes. Con el fin de asegurar un alto nivel de servicio, es esencial gestionar una organización basada en indicadores operativos para dirigir las operaciones hacia el plan estratégico. Los terminales de contenedores están insertados en este contexto, donde el esfuerzo de gestión y los recursos financieros deben equilibrarse para lograr la mejor utilidad de todo el sistema. Con eso en mente, esta investigación tiene como objetivo establecer las dimensiones de los indicadores operativos más relevantes de los terminales de contenedores brasileños aplicando el método Analytic Hierarchy Process (AHP), proporcionando un conjunto de indicadores como referencia para los tomadores de decisiones. Para lograr este objetivo, llevamos a cabo una revisión sistemática en las bases de datos Scopus, identificando 38 indicadores operativos que fueron comparadas en pares por gerentes que representaron a 7 terminales de contenedores brasileños, responsables del manejo del 71% del volumen de contenedores de Brasil. Esta investigación ha hecho contribuciones prácticas y gerenciales, clasificando los indicadores operativos para ayudar a los tomadores de decisiones a gestionar los terminales de contenedores hacia su estrategia.

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% of international cargo trade, shippers/consignees have broken distances barriers and started to seek providers that fulfill better their expectations, enhancing the competitiveness throughout the world (Haralambides, 2019). The outstanding increase of 74,6% in dry cargo volume loaded and carry by container since the year 2000 (UNCTAD, 2019) has putting pressure on seaports, that are facing operational challenges related to terminal capacity, fairway drafts, equipment to handle those vessels, and, in particular, operational efficiency (Khaslavskaya & Roso, 2020).

In practice, seaports are the most important and indispensable actor in container transport systems, composed of a terminal with docks and yard, where containers are positioned, temporarily stored and arrived/leaved by means of vessel operation or inland transportation (truck or rail) (Fazi & Roodbergen, 2018; Haralambides, 2019). In particular, seaports are ecosystems in which a large and heterogeneous set of stakeholders interact and implement a variety of articulated and interconnected business operations and processes (Simoni et al., 2022). However, nowadays container terminals are much more than places for transferring cargo between different modes of transport. They offer a wide range of services to exploit potential economies of scale, acting as gateways to access international markets, which requires an alignment of seaside, intermodal/multimodal and landside logistics to achieve an efficient movement of the physical (i.e., cargos) and non-physical (i.e., information) flows (Ha et al., 2017).

Such complexity of operational roles makes the seaport choice a complex issue by customers. A review of prior research on seaport choice conducted by Rodrigues et al. (2021) suggests that research on seaport choice that touches upon parameters such as seaport effectiveness and maritime line optimization are well established in the literature, as stated in Talley and Ng (2013), and Moya and Valero (2016). These authors reinforce that customers are oriented to choose seaports that provide more reliable, efficient and economic services, making the operational indicators of a seaport an important base for customer's choice (Jiang et al., 2015; Talley & Ng, 2013).

The operational indicators of the container terminal allow categorizing the services provided in each seaport, highlighting the current performance and smoothing the managerial decisions based on data (Júnior, 2008). Despite the relevance, managing a container terminal based on operational indicators may become a complex issue, especially due to their quantity and complexity to assess. Thus, some questions that emerge are: i) what are the set of operational indicators to manage a container terminal? ii) Which indicators should be prioritized? This problem is classified as a multi-criteria problem that could be treated as sorting problem. One of the most applied methods for sorting problems is the AHP (Analytic Hierarchy Process), developed by Thomas Saaty (Vaidya & Kumar, 2006); this method is widely applied when problems require consideration of quantitative and qualitative factors, such as operational and socioeconomic decisions (Subramian & Ramanathan, 2012).

Based on the questions stated, this research aims to establish and rank the dimensions of the operational indicators of Brazilian container terminals, according to the view of experts by the AHP method, in order to provide a set of benchmarks dimensions to aid seaport's practitioner's decision-making. With that in mind, first it was identified the dimensions of existing operational indicators related to container terminals through a systematic review. Second, the operational indicators were pairwise compared by seaport's expert opinions, getting the relevance of each operational dimension. Lastly, the AHP method was applied in order to sort the operational indicators, resulting in relevant theoretical and managerial insights.

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, we present a review of previous literature on the operational indicators in container terminals. Section 4 details the methods and tools applied in this research, focusing on the multi-criteria AHP method. Section 5 presents the results and discussions, where we articulate the analysis and the main insights of the research, concluding the article with the theoretical and managerial contributions in Section 6.

2. STUDY CONTEXT

Seaport is a complex logistic network that exist in very different forms and arrangements under different terms around the world, especially transportation infrastructure, functionality, maturity level, ownership, and initiation processes (Khaslavskaya & Roso, 2020). The differences of logistic infrastructure in each region requires a depth study to catch specific characteristics. However, studies covering this topic are concentrate especially in Asian and European countries, while South American and African countries had low representativeness (Rodrigues et al., 2021). Fulfilling this literature gap, the present study has focused in Brazil.

Brazil is the largest country in South America, covering an area of 8.5 million km², making it the world's fifth-largest country. With a population estimated at over 211 million, it is also the sixth most populous country in the world (IBGE, 2020). Economically, Brazil is the 9th economy in the world, with a GDP of US$7.4 trillion, exporting US$209 billion and importing US$158 billion in 2020 (MDIC, 2021). Furthermore, Brazil is the 20th largest container-handling economy in the world, handling more than 10 million TEUs per year; just Santos seaport hub in São Paulo state is responsible for 45% of this volume (ANTAQ, 2022; UNCTAD, 2019). Given the above factors, Brazil very clearly plays a major role in global international trade and maritime cargo transportation.

In recent years, Brazil has seen significant growth in its container terminal industry, with several terminals emerging as key players. The seaport of Santos, located in the state of São Paulo, is the largest container seaport in Brazil, handling approximately 4.5 million TEUs (twenty-foot equivalent units), annually, in 2022 (ANTAQ, 2022). It is followed by the Seaport of Navegantes and Paranaguá, both located in the south of Brazil, handling around 1.1 million per year. Other major container terminals in Brazil include the seaports of Rio Grande, Itajaí, and Suape. The volume of container handling in Brazil is expected to continue to grow, driven by the country's expanding trade partnerships and its growing consumer market. This context reveals the relevance to identify the main operational factors, aiding seaport's practitioners to manager their operations and improve the competitiveness.

3. THEORETICAL BACKGROUND

The performance indicators are crucial in strategic management of any organization and can occur in a variety of forms and complexities. Overall, indicators are indexes to measure the greatness of a manufacturing or administrative process, determining if it is inserted within acceptable parameters (Martins & Laugeni, 2005). Moreover, it is also a measure that ensures the evaluation of particular attributes, providing the basis for decision making (Niedritis, Niedrite, & Kozmina, 2011).

The literature affirms that metrics encourage managers and employees to make the decisions that they believe are the best to achieve the goal (Kaplan & Norton, 1992; Drucker, 1954). If the metrics are chosen carefully, managers and employees enhance the chances to make better decisions, allowing the company to maximize its profits in a long term (Hauser & Katz, 1998). One of the main strategic management tools that help organizations track and measure their progress towards achieving their goals and objectives is the Balanced Scorecard (BSC) (Kaplan & Norton, 1992). However, many executives, seeking to create value for shareholders, also rely on their intuition in the choice of indicators, which can lead to bad decisions (Mauboussin, 2012).

The seaport's operational indicators are closely related with the customer's choice to use such seaport as logistic operator. A review of prior research on seaport-hinterland choice conducted by Rodrigues et al. (2021) suggests that research on seaport choice that touches upon parameters such as seaport effectiveness and maritime line optimization are well established in the literature. Examples of this literature being Talley and Ng (2013), and Moya and Valero (2016). In addition to studies focused on seaport effectiveness and maritime line optimization, other studies have examined intermodal connection decision and network optimization (Tran, Haasis, & Buer 2017). However, despite these studies, little attention has been given to sort the seaport's operational indicators.

Operations in container terminals are wider and more complex than simply loading and unloading container to/from the ships. These activities can be represented by operational indicators such as storage capacity, number of docking berth, cranes/ship-to-shore to load/discharge the ships, equipment capacity, berthing window, container dwell-time, truck cycle time, container handling per day and gate productivity (Rashidi & Tsang, 2013). From another perspective, Felicio, Caldeirinha, and Dionísio (2014) found 5 main characteristics to influence container terminal operational performance: i) seaport location; ii) seaport-hinterland network (land side connectivity); iii) maritime shipping services; iv) dynamism of port authorities and v) seaport organization and logistics integration.

The dimensions of the performance indicators in seaports show the operational efficiency and should be useful for shippers and consignees, as well for seaports' managers to making decisions to align the operations with the strategic plan. Some examples of operational indicators quoted by Caggiani et al. (2012) are productivity in its various applications, the equipment utilization rate, operating costs, the pier draft, the crane/ship-to-shore length, the yard area and the amount of handling equipment. According to Largen and Sharypova (2013), the intermodal connectivity also appears as a relevant operational indicator, since many port authorities and managers have the ambition to deal with a greater share of volumes using multimodal transport. However, the increased use of intermodal transport requires better connectivity throughout seaport-hinterland, which is not the case of Brazil, with a low density of rail network (ANTF, 2019).

The logistic operations, especially in large container terminals, have achieved a level of complexity that requires knowledge about all variables and how they interact in the system. To meet the operational challenges and become competitive, container terminals have to innovate and often automate equipment to optimize their logistics processes (Rashidi & Tsang, 2013). However, there are no current standardized set of indicators in order to measure the degree of specialization and efficiency of activities in seaports. With that in mind, the literature offers a set of operational indicators from 14 papers, used as reference in this research (Frame 1).

Frame 1. Container terminal operational indicators.

Indicator	Objective	Reason	Reference
Length and depth of the quay	To determine the quay features (length and depth) for berthing ships	Given the increase in the size of container ships, terminals with larger piers are necessary	Al-Eraqi et al. (2010); Feng et al. (2011); Caggiani et al. (2012); Rios & Souza (2014)
Yard capacity	To assess the container storage capacity	To identify the occupancy/congestion of the terminal	Al-Eraqi et al. (2010); Yeo et al. (2011); Caggiani et al. (2012); Rios & Souza (2014)
Warehouse capacity	To assess the warehouse storage capacity	To identify the occupancy/congestion of the warehouse	Al-Eraqi et al. (2010); Yeo et al. (2011); Caggiani et al. (2012); Rios & Souza (2014)
Infrastructure investment	To measure the amount of investment on the terminal infrastructure	To enable to assess the payback and the return on investment	Yeo, Roe & Dinwoodie (2011)
Intermodal connectivity	To identify with which modals the container terminal is connected	Intermodal network reduces transportation costs and improve the competitiveness	Baldassara et al. (2010); Yeo et al. (2011); Feng et al. (2011); Largen & Sharypova (2013)
Operational reliability	This is a measure of the probability that a system (ship operation) will operate without failure for a given period of time.	To meet the customers' requirements/agreements and to comply with shippers' berthing windows	Pun & Nurse (2010); Rashidi & Tsang (2013); Lam & Song (2013); Tapia et al. (2014)
Equipment reliability	This is a measure of the probability that equipment	Useful data for the maintenance plan	Pun & Nurse (2010); Rashidi & Tsang (2013); Lam & Song (2013)

	will operate without failure for a given period of time.		
Workforce cost	To measuring the amount of money used for paying operational employees	To control the operational costs	Huang et al. (2010); Caggiani et al. (2012); Tapia et al. (2014)
Operational cost	To measuring the cost related to any operational activity	To price services, to identify losses, to track and reduce cost and to optimize resources	Huang et al. (2010); Yeo, Roe & Dinwoodie (2011); Caggiani et al. (2012); Lam & Song (2013)
Maintenance cost	To measure and control maintenance costs	To assess maintenance effectiveness	Pun & Nurse (2010); Huang et al. (2010); Feng et al. (2011); Lam & Song (2013)
Handling volume demand	To measure the demand for handle containers inside the terminal	To evaluate trade levels and the terminal operational service capacity	Al-Eraqi et al. (2010); Huang et al. (2010); Yeo et al. (2011); Feng et al. (2011); Rashidi & Tsang (2013)
Equipment availability	To identify whether the equipment is available when needed	Useful data for the maintenance plan	Pun & Nurse (2010); Rashidi & Tsang (2013); Lam & Song (2013); Tapia et al. (2014)
Container loss/damage	To measure the frequency of container loss/damage	To meet the customer requirements/agreements	Yeo et al. (2011)
Number of reefer plugs	To determine the reefer's container capacity	Capacity to store reefer's container	Feng et al. (2011); Rios & Souza (2014)
Warehouse occupation	To determine the occupation in the seaports' warehouse	To identify the occupancy/congestion of the warehouse	Al-Eraqi et al. (2010); Yeo et al. (2011); Nooramin et al. (2011)
Yard occupation	To determine the occupation in the yard area	To identify the occupancy/congestion of the terminal	Al-Eraqi et al. (2010); Yeo et al. (2011); Nooramin et al. (2011)
Ship load/discharg e productivity	To measure how many containers are load/discharge per hour in a ship operation	To estimate the operation time and to track the productivity	Pun & Nurse (2010); Yeo et al. (2011); Nooramin et al. (2011); Cartenì & Luca (2012); Caggiani et al. (2012); Tapia et al. (2014)
Berth productivity	To assess how many ships, perform in a berth per month	To track the efficiency of a berth	Pun & Nurse (2010); Yeo et al. (2011); Nooramin et al. (2011); Cartenì & Luca (2012); Caggiani et al. (2012)
Equipment productivity	To measure the performance of the equipment	To allocate resources and aid operational and maintenance decision-making	Pun & Nurse (2010); Huang et al. (2010); Nooramin et al. (2011); Cartenì & Luca (2012); Caggiani et al. (2012); Rashidi & Tsang (2013)
Distance between the berth and the yard block	To measure the distance traveled by trucks	To improve the storage plan, reducing transportation distance	Feng et al. (2011); Caggiani et al. (2012)
Additional equipment	To measure the quantity of forklifts, reach stackers, etc.	To certify if the seaport has the required equipment for the logistic operation	Yeo et al. (2011); Feng et al. (2011); Rios & Souza (2014)
Quantity of ship-to-shore/cranes	To measure the ship load productivity of the terminal	Ship-to-shore/cranes are the most relevant seaport equipment, responsible for the ship load productivity	Huang et al. (2010); Yeo et al. (2011); Feng et al. (2011); Caggiani et al. (2012); Rios & Souza (2014)
Quantity of TEUs handled	To measure the volume of container handled in the terminal	The seaport's profit come especially from handling container	Yeo et al. (2011); Feng et al. (2011)

Quantity of trucks	To measure the capacity to transport containers	This aid to assess the capacity of the seaport	Feng et al. (2011); Cartenì & Luca (2012); Rashidi & Tsang (2013)
Truck productivity	To measure how many containers were transported by truck by shift	To measure the equipment productivity	Yeo et al. (2011); Cartenì & Luca (2012); Rashidi & Tsang (2013)
Equipment breakdowns	To measure the amount of breakages during operation shift	This indicator is an input for the maintenance plan	Pun & Nurse (2010); Rashidi & Tsang (2013)
Equipment productivity	To measure the equipment usage rate	To schedule maintenance, operational shifts and measure productivity	Pun & Nurse (2010); Cartenì & Luca (2012); Rashidi & Tsang (2013)
Stowage plan distribution	Quantity of ship-to-shore/cranes that a stowage plan allows to work	More cranes operating in the vessel results in more productivity	Feng et al. (2011); Rashidi & Tsang (2013)
Waiting time for trucks	To measure the waiting time of trucks waiting to be loaded/discharged in the terminal	To assess the terminal congestion and the truck productivity	Yeo et al. (2011); Feng , et al. (2011); Nooramin et al. (2011); Cartenì & Luca (2012); Rios & Souza (2014)
Container dwell time in the terminal	To measure the average time that the container stayed stored in the terminal	The seaport charges the customer according to the storage time	Baldassara et al. (2010); Cartenì & Luca (2012); Rashidi & Tsang (2013)
Free dwell time in the terminal	To measuring the quantity of cargo that stayed free of charge	To assess if the customers are using this benefit	Cartenì & Luca (2012); Rashidi & Tsang (2013)
Average waiting time of the ship	To measure the time between the ship arrived and the operation began	To comply with customers agreements	Yeo et al. (2011); Fen et al. (2011); Cartenì & Luca (2012)
Average operation time	To estimate how many containers can be loaded/discharged per hour	This aid to schedule a vessel sailing time and operational shifts	Pun & Nurse (2010); Baldassara et al. (2010); Cartenì & Luca (2012)
Truck travel time	To measure the truck travel time from the quay to the yard	It allows to estimate the number of trucks required per shift	Nooramin et al. (2011); Rashidi & Tsang (2013)
Equipment waiting time	To estimate the equipment unproductive time	To better schedule equipment per work shift	Pun & Nurse (2010); Feng et al. (2011); et al. (2011); Cartenì & Luca (2012); Lam & Song (2013); Rios & Souza (2014)
Dwell time of external truck	To measuring the time between external truck, arrive and leave the terminal	It allows to measure the yard productivity/congestion	Pun & Nurse (2010); et al. (2011); Cartenì & Luca (2012); Rios & Souza (2014)
Ship berthing time	To measure the total time the ship was docked at terminal	The docking time cannot be greater than the vessel window	Pun & Nurse (2010); Yeo et al. (2011); Feng et al. (2011)
Gate productivity	To identify the number of external trucks arriving/leaving the terminal	To identify the volume handled per day and to estimate the terminal congestion	Pun & Nurse (2010); Yeo et al. (2011); Cartenì & Luca (2012); Rashidi & Tsang (2013)
Equipment operating speed	To identify the equipment performance	To assess the equipment productivity and schedule the equipment for the shift	Pun & Nurse (2010); Yeo et al. (2011); Feng et al. (2011); Cartenì & Luca (2012); Rashidi & Tsang (2013)

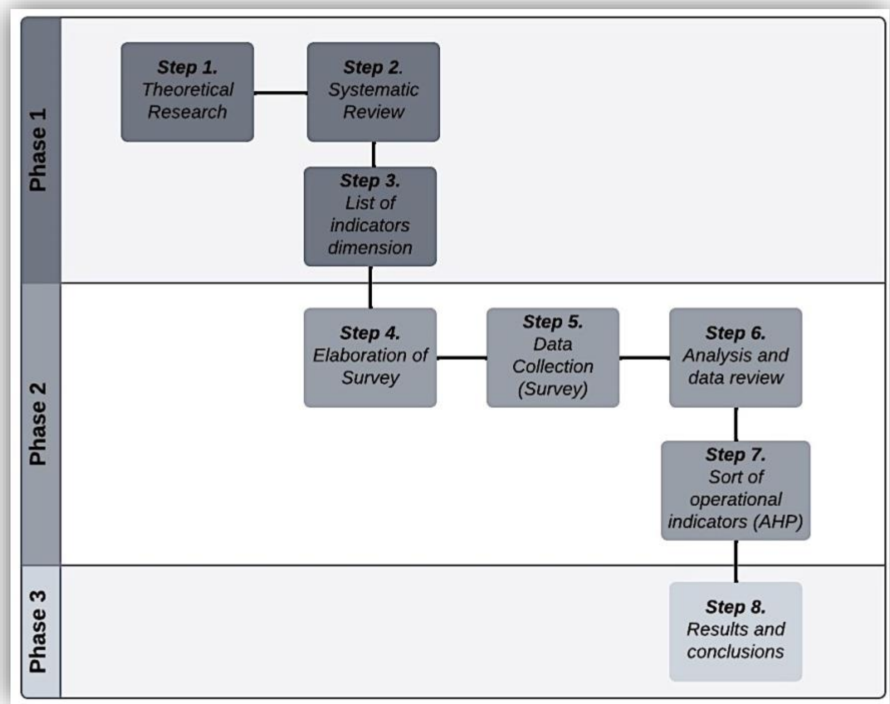
Source: Authors

Based on the above structure, the AHP method was applied in order to pairwise comparison of the operational indicators by seaports' managers, looking for sorting and finding the most relevant to be considered for seaport's operational management decision-making. The literature presents some cases of AHP in seaports decision-making. The study of Cruz, Ferreira and Azevedo (2013) discussed the key factors of seaport competitiveness from the perspective of Iberian seaports stakeholders, demonstrating that the relative importance of the factors varies among the stakeholders. From the perspective of risk, Lamii et al. (2022) used AHP to present a hierarchy that simplifies the complexity of the seaport logistic system in an organized structure, and to analyze and assess risk factors based on the identified criteria. Lastly, AHP was also applied in locations problems, aiding decision-makers to select the best location for seaports, dry ports and other logistics facilities (Božičević et al., 2021).

4. METHODS AND TOOLS

This research followed 3 phases and 7 steps methodology, as follows in Figure 1. The focus of the first phase of the study was to identify, by the literature, the operational indicators of container terminals. With that in mind, first a theoretical research was performed, getting relevant information to then conduct a systematic review in step 2.

Figure 1. Research phases.



Source: Authors

The systematic review followed the procedure developed by Tranfield, Denyer and Smart (2003). Our focus here was to identify the dimensions of the operational indicators of Brazil's container terminals. The keywords searched in the databases were "container port", "container seaport" and "container terminal", with the logic 'AND' to "performance indicator" and "operational indicator" for title, keywords and abstract. By searching in the

Scopus database, restricting the publication year from 2010 to 2015, it was obtained total of 51 publications. These articles were filtered considering the scope of the research to discuss/present the main operational indicators used to manage container terminals. After filtering the database, 14 papers were selected to be included in this study, concluding the step 3 and the phase 1 of this research.

The second phase was concentrated in build a research instrument to get the seaports' managers perspective about the relevance of the operational indicators, enabling to sort them. In step 4, the survey instrument was built by Google Docs. To pairwise comparing the indicators, a Likert scale of 9 points was used (Saaty, 1994). The survey instrument was tested with Master's degree students of Universidade Federal do Paraná. After the required adjusts, the survey instrument was sent to the target audience to collect the data (step 5).

Our target audience was managers of container terminals in Brazil with container handling higher than 100,000 TEUs per year, thus eliminating shipping agencies and small seaports that are not container terminals, resulting in 15 container terminals. This target is aligned with the definition of skill required for a decision-making described by Saaty and Alexander (2013) and Saaty (1994), which defined that participants AHP should know and experience the problem to be studied. In this way, from the fifteen container terminals that were contacted, we got seven answers from the survey instrument. The seaports' managers that participated in this research were responsible for handling 8.342.157 TEUs in 2022, responding for 71% of the total volume of container handled in Brazil (ANTAQ, 2022) (Table 1).

Table 1. Volume of TEUs handled by the target seaports.

Container Terminal	Volume of TEUs handled (2022)
Porto Itapoá	885.822
Portonave	1.149.715
DP World	931.542
Paranaguá	1.114.097
Rio Grande	517.665
Santos Brasil	3.518.312
Vitória	225.004

Source: ANTAQ (2022)

After collecting the survey, the data was reviewed (step 6) to avoid missing values or other mistakes. In step 7, we applied the AHP method to sort the operational indicators of container terminals, aggregating the perspective of all managers. Based on the results, we articulated the discussions and main contributions of this research, in step 8. In the next topic, we briefly present the AHP method.

4.1 MULTI-CRITERIA DECISION AID AND AHP METHOD

A multi-criteria decision problem is a type of decision that involves making a choice between multiple alternatives based on multiple criteria or factors. This type of problem arises when the decision-maker needs to consider several factors that are important for achieving their objectives, such as cost, time, quality, risk and social impact (Keeney, 1992). In general, there are four questions: i) choice: the process of selecting an option from a set of alternatives; ii) sort/rank: involves sorting items according to their priority/relevance defined by the decision-maker; iii) classification: the process of assigning items to different categories based on their properties or characteristics; iv) description: involves characterizing a phenomenon or object using words or other forms of language (Almeida, 2013).

Actually, there are many multi-criteria methods to aid decision-making, divided in two main categories: Outranking and Compensation methods (Almeida, 2013). The Outranking methods, also known as preference-based methods, are methods that compare alternatives to each other based on the extent to which one alternative outranks the others in terms of the criteria being evaluated. Examples of outranking methods include the Preference Ranking Organization Method for Enrichment Evaluations (PROMETHEE) and the Elimination Et Choix Traduisant la Réalité (ELECTRE). The Compensation methods, also known as value-based methods, aggregate scores or weights for the criteria to obtain an overall score or ranking for each alternative. In compensation methods, the criteria are typically combined into a single utility function that represents the decision-maker's preferences. Examples of compensation methods include the simple additive weighting (SAW), Macbeth, TOPSIS and AHP (Almeida, 2013).

The AHP method is one of the most applied multi-criteria methods, with applied cases in airline companies (Mahtani & Garg, 2018), urban public transport (Nosal & Solecka, 2014), supplier segmentation (Rezaei & Ortt, 2013) and also port performance indicators (Ha & Yang, 2017). A recent systematic review of AHP publications was made by Gonçalves *et al*. (2021), revealing the practical and theoretical relevance of this method. This method uses pairwise comparisons, which means it compares the level of relevance of a particular item or feature over another. These comparisons can be taken from actual measurements or from a fundamental scale, which reflects the relative strength, preferences, feelings and subjective opinions (Saaty, 1987; Subramanian & Ramanathan, 2012). AHP also provides an effective framework for the decision-maker group, imposing a discipline through the stages of the process. The need to add a numerical value to each variable of the problem helps to maintain consistency between the trials, increasing the consistency of judgments and the reliability of AHP as a decision-making tool (Saaty, 2012).

To details all AHP algorithm is not part of this research scope. However, the main steps may be simplified in 5 steps as follows (Saaty, 2012): to define the decision problem and to identify the criteria and alternatives; ii) to construct a hierarchy of decision criteria and alternatives, where ‘W’ is the weight of each criterion, and ‘P’ is the priority of each alternative; iii) to compare the criteria and alternatives pairwise, and assign a relative weight or priority to each. Here, A_{ij} is the relative importance of criterion ‘i’ to criterion ‘j’, and B_{ijk} is the relative importance of alternative ‘k’ to criterion ‘i’. It can be represented in a square matrix, where the diagonal elements are all equal to 1, and the off-diagonal elements are reciprocals of each other. In this way, $A_{ij} = 1/A_{ji}$, and $B_{ijk} = 1/B_{ikj}$.

Step iv) is the consistency check of the pairwise comparisons, calculating the Consistency Ratio (CR), defined as $(\lambda_{max} - n)/(n-1)$, where λ_{max} is the maximum eigenvalue of the pairwise comparison matrix, and 'n' is the number of criteria or alternatives. The CR should be less than 0.1 for the comparisons to be considered consistent. Then, the step v) calculates the priorities by aggregating the pairwise comparison values. Let C_i be the priority of criterion 'i', and A_{ik} be the priority of alternative 'k'. The priority of each criterion is given by $C_i = \sum_j (A_{ij} * W_j)/\sum_j W_j$, where Σ_j denotes the sum over all criteria 'j'. The priority of each alternative is given by $A_{ik} = \sum_i (B_{ijk} * C_i)$. More details of the AHP algorithm follows in Saaty (1987), Subramanian and Ramanathan (2012) and Saaty (2012).

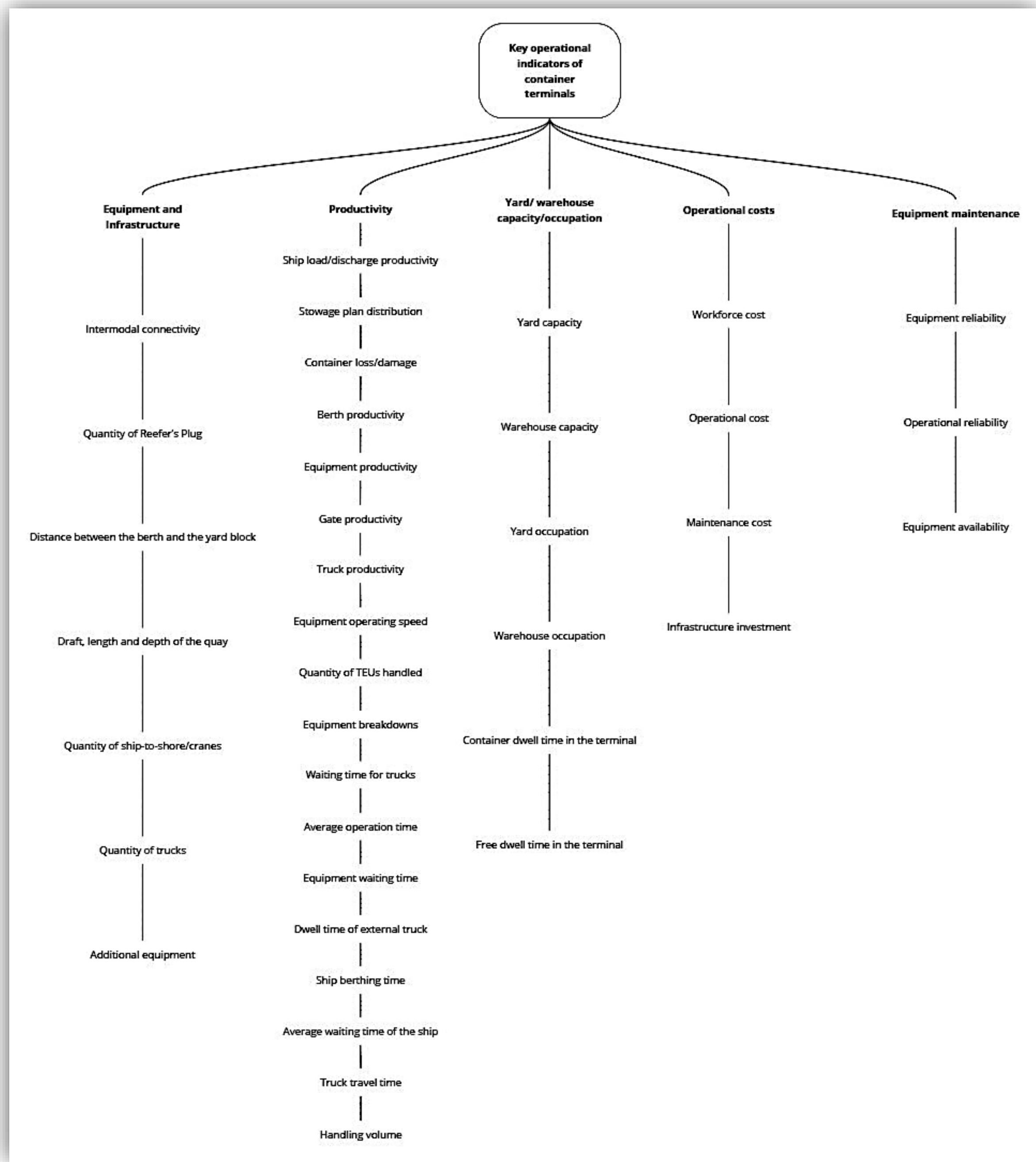
5. RESULTS AND DISCUSSION

The AHP method was applied to sort the operational indicators of container terminals based on the pairwise comparison made by the specialists. The set of operational indicators were aggregated in 5 dimensions according to their specificity, in order to facilitate the pairwise comparison and the indicators' sort. The dimensions were: i) equipment and infrastructure; ii) productivity; iii) yard/ warehouse capacity/occupation; iv) operational costs; v) equipment maintenance (Figure 2).

First, the seaport's managers pairwise compared the operational dimensions of indicators, defining their relative preference. Applying the AHP on data obtained by the survey instrument and aggregating the perspective of all managers, the first result was the dimension's sort, as presented in Table 2. This output reveals that the productivity dimension is the most important, responding for 37% of the relative priority, followed by operational costs (24%), equipment and infrastructure (15%), yard/warehouse capacity/occupation (13%) and equipment maintenance (10%). This result agrees with the study of Jamain, Zakaria and Satar (2023), reinforcing the relevance to manage productivity indicators in order to become more competitive. In this way, a more productive seaport will draw attention from shippers and ship-owners, which are looking for faster logistics services.

We've applied the same approach to sort the operational indicators in each dimension, ranking them in Table 3. Regarding the operational indicators, ship load/discharge productivity (11%) was the most relevant for the specialists. The ship load/discharge productivity dictates the time that the vessel stays berthing in the seaport, making this indicator relevant for the seaport competition, where ship carriers' looks for fast operations to fulfill theirs port calls along their trip on time. Also important is quantity of TEUs handled (11%) by the seaport, because it directly impacts the seaport's economic performance and competitiveness. The more containers a seaport can handle, the more goods and products it can transport, resulting in increased revenue and trade activity.

Figure 2. Set of dimensions and operational indicators.



Source: Authors

Table 2. Preference matrix of operational dimensions.

Dimensions	Equipment and infrastructure	Productivity	Yard/warehouse capacity/occupation	Operational costs	Equipment maintenance	Sort
Equipment and infrastructure	1	0,62	1	0,53	1,26	15%
Productivity	1,6	1	4,02	1,81	3,39	**37%**
Yard/warehouse capacity/occupation	1	0,25	1	0,58	1,47	13%
Operational costs	1,87	0,55	1,72	1	2,36	24%
Equipment maintenance	0,79	0,29	0,68	0,42	1	10%

*CI= 0,022; RI(5) = 1,11; CR = 0,02. Source: Authors

Table 3. Preference matrix of productivity indicators.

Productivity indicators	Ship load/discharge productivity	Stowage plan distribution	Equipment productivity	Berth productivity	Equipment breakdowns	Gate productivity	Truck productivity	Equipment operating speed	Quantity of TEUs handled	Container loss/damage	Handling volume demand	Waiting time for trucks	Average operation time	Truck travel time	Equipment waiting time	Dwell time of external trucks	Ship berthing time	Average waiting time of the ship	Sort
Ship load/discharge productivity	1	2,27	1,81	2,19	2,89	3,11	2,47	2,04	1,26	2,19	2,54	1,54	2,27	2,11	3,47	1,66	2,33	1,87	11%
Stowage plan distribution	0,44	1	0,46	0,85	1,17	1,35	1,26	0,85	0,41	0,63	0,5	1,03	0,79	1,72	1,47	1,03	0,89	0,85	4%
Equipment productivity	0,55	2,17	1	1,58	1,72	2,33	1,66	1,47	0,85	1,23	1,72	2,27	1,85	1,94	3,19	2,33	1,85	2,54	8%
Berth productivity	0,46	1,17	0,63	1	1,85	1,7	1,35	0,92	0,47	0,6	0,76	1,16	0,73	0,92	1,47	0,7	0,85	1,08	5%
Equipment breakdowns	0,35	0,85	0,58	0,54	1	1,79	1,47	0,85	0,46	0,64	0,44	0,81	0,55	0,55	0,95	0,95	0,76	0,65	4%
Gate productivity	0,32	0,74	0,43	0,59	0,56	1	0,58	0,73	0,58	1,04	0,39	1,01	0,6	0,79	1,72	0,93	0,73	0,73	4%
Truck productivity	0,4	0,79	0,6	0,74	0,68	1,72	1	0,55	0,44	0,61	0,65	0,65	0,6	0,44	0,83	0,51	0,6	0,6	3%
Equipment operating speed	0,49	1,17	0,68	1,09	1,17	1,37	1,81	1	0,5	0,52	0,68	0,79	0,6	0,85	2,09	0,76	0,55	0,76	4%
Quantity of TEUs handled	0,79	2,45	1,17	2,11	2,19	1,72	2,27	2,02	1	2,27	2,27	3,23	2,36	3	4,47	4,26	2,45	3,35	11%
Container loss/damage	0,46	1,58	0,81	1,66	1,57	0,96	1,64	1,92	0,44	1	0,92	1,03	0,85	1,16	2,02	1,16	0,75	0,64	5%
Handling volume demand	0,39	2,02	0,58	1,32	2,27	2,54	1,54	1,47	0,44	1,09	1	1,54	1,47	1,42	2,73	2,02	1,47	1,72	7%
Waiting time for trucks	0,65	0,98	0,44	0,86	1,23	0,99	1,54	1,26	0,31	0,98	0,65	1	0,68	0,79	1,94	0,79	0,6	0,51	4%
Average operation time	0,44	1,26	0,54	1,37	1,81	1,66	1,66	1,66	0,42	1,17	0,68	1,47	1	2,04	3,35	2,27	1,26	1,47	6%
Truck travel time	0,47	0,58	0,51	1,09	1,81	1,26	2,27	1,17	0,33	0,86	0,7	1,26	0,49	1	2,19	0,79	0,6	0,7	4%
Equipment waiting time	0,29	0,68	0,31	0,68	1,05	0,58	1,2	0,48	0,22	0,5	0,37	0,51	0,3	1,26	1	0,42	0,26	0,36	3%
Dwell time of external trucks	0,6	0,98	0,43	1,44	1,05	1,08	1,94	1,32	0,23	0,86	0,5	1,26	0,44	1,66	2,36	1	0,26	0,27	4%
Ship berthing time	0,43	1,13	0,54	1,17	1,32	1,37	1,66	1,81	0,41	1,34	0,68	1,66	0,79	1,42	3,82	3,92	1	1,54	6%
Average waiting time of the ship	0,53	1,17	0,39	0,93	1,54	1,37	1,66	1,32	0,3	1,56	0,58	1,94	0,68	1,42	2,79	3,64	0,65	1	6%

*CI= 0,047; RI(15) = 1,59; CR = 0,03. Source: Authors

The second dimension that we detail is the operational cost indicators, as presented in Table 4. The infrastructure investment (29%) was the main relevant according to specialists. Seaports require significant investment in infrastructure to maintain and upgrade their facilities, equipment and technologies to meet the growing demand for shipping services. Such investments can help to reduce port congestion, increase handling capacity, enhance cargo handling and storage and improve overall port performance (Munim & Schramm 2018). The other indicators ranked were operational (27%) and workforce costs (25%). This result signalizes that seaport's managers are aware of the impact that operational and workforce costs may cause in the seaport competitiveness. With that in mind, many ports are investing in new equipment and technologies, especially the automated seaports (Kim, Kim, & Kang, 2022).

Table 4. Preference matrix of operational costs indicators.

Operational costs	Workforce cost	Operational cost	Maintenance cost	Infrastructure investment	Sort
Workforce cost	1	1	1,37	0,79	25%
Operational cost	1	1	1,35	1,12	27%
Maintenance cost	0,73	0,74	1	0,62	19%
Infrastructure investment	1,26	0,9	1,6	1	**29%**

*CI= 0,0041; RI(4) = 0,9; CR = 0,0046. Source: Authors

Then we focused to sort the equipment and infrastructure indicators, as presented in Table 5. The most relevant indicator was quantity of STS/cranes (22%) and draft and length of the quay (21%). A higher quantity of STS cranes can increase the seaport's handling capacity, reduce vessel waiting time and improve overall terminal productivity. The Draft and length are also important as it determines the size of vessels that can enter and leave the port. Seaports with deeper drafts can accommodate larger vessels, which can result in sparing of scale, lower transportation costs and increasing competitiveness. Finally, the length of the quay determines the number of berths available for vessels and can also impact handling capacity and productivity (Bierwirth & Meisel, 2010).

Table 5. Preference matrix of equipment and infrastructure indicators.

Equipment and infrastructure	Intermodal connectivity	Quantity of reefers' plugs	Distance from berth to yard	Draft and length of the quay	Quantity of STS/cranes	Quantity of trucks	Additional equipment	Sort
Intermodal connectivity	1	1,12	0,51	0,27	0,26	0,35	0,38	6%
Quantity of reefers' plugs	0,9	1	0,46	0,26	0,34	0,39	0,34	6%
Distance from berth to yard	1,68	2,19	1	0,5	0,46	0,46	0,43	10%
Draft and length of the quay	3,69	3,92	1,99	1	1,08	1,26	1,08	21%
Quantity of STS/cranes	3,88	2,97	2,17	0,93	1	1,26	1,58	**22%**
Quantity of trucks	2,86	2,54	2,33	0,79	0,79	1	1,37	18%
Additional equipment	2,63	2,97	2,51	0,93	0,63	0,73	1	17%

*CI= 0,012; RI(4) = 1,35; CR = 0,009. Source: Authors

Regarding the yard/warehouse capacity/occupation dimension, the main indicator was yard occupation (28%) and capacity (23%), as presented in Table 6. Adequate yard capacity is necessary to accommodate the volume of containers handled by the terminal, while efficient yard occupation is required to optimize the use of available space and minimize the time and cost of container movements. Thus, managing yard capacity and occupation are keys to reducing congestion, improving throughput and enhancing the overall performance of a container terminal (Lee & Kim, 2013). Lastly, we observed that the indicators regarding warehouse were with the less relevance, which indicates that the service to store the disaggregated cargo are not a critical issue for Brazilian seaports.

Table 6. Preference matrix of yard/warehouse capacity/occupation indicators.

Yard/warehouse capacity/occupation	Yard occupation	Warehouse occupation	Yard capacity	Storage Capacity	Free dwell time in the terminal	Container dwell time in the terminal	Sort
Yard occupation	1	3,92	1,47	2,66	2,02	1,79	**28%**
Warehouse occupation	0,26	1	0,34	0,85	0,29	0,3	6%
Yard capacity	0,68	2,97	1	3,6	1,54	1,32	23%
Warehouse Capacity	0,38	1,17	0,28	1	0,46	0,44	8%
Free dwell time in the terminal	0,5	3,47	0,65	2,19	1	0,79	16%
Container dwell time in the terminal	0,56	3,35	0,76	2,27	1,26	1	18%

*CI= 0,014; RI(7) = 1,24; CR = 0,011. Source: Authors

The last indicators were from equipment maintenance dimension, as follows in Table 7. The most relevant indicator was operational reliability (59%). A reliable terminal ensures that cargo is delivered on time and in good condition, which is essential for meeting the needs of customers and maintaining their trust. This requires efficient and effective management of all terminal operations, especially equipment maintenance. By ensuring operational reliability, container terminals can reduce the risk of delays and disruptions, increase throughput and productivity and enhance their reputation and market position.

Table 7. Preference matrix of equipment maintenance indicators.

Equipment maintenance	Operational reliability	Equipment availability	Equipment reliability	Sort
Operational reliability	1	3,08	2,73	**59%**
Equipment availability	0,32	1	1,17	21%
Equipment reliability	0,37	0,85	1	20%

*CI= 0,0043; RI(3) = 0,58; CR = 0,0074. Source: Authors

Summarizing the results of this research, Table 8 presents the rank of operational dimensions, highlighting the 3 most relevant operational indicator of each dimension. The main contribution of this sort of indicators is that it can be use in other multi-criteria problems as weights for the inter-criteria analysis. Furthermore, considering the amount of data an indicator that should be managed in a container terminal, a more specific set of indicators (the most relevant) is relevant for managers, highlighting the ones that they should keep in mind in order to become more competitive.

Lastly, we conclude that operational indicators provide a quantitative measure of the performance of various aspects of terminal operations, including vessel operations, yard operations, equipment maintenance and supply chain coordination. By tracking these indicators, terminal managers can identify areas of weakness and take corrective action to improve performance. Operational indicators also help to ensure that terminal operations are aligned with the needs of customers, providing timely and reliable services that meet their expectations (Rodrigues et al. 2021). Overall, managing container terminals using operational indicators is critical for enhancing performance, reducing costs and maintaining a competitive edge in the market.

Table 8. Rank of dimensions and operational indicators.

Operational Dimension	Relative Preference	Operational Indicator	Relative Preference
Productivity	37%	Quantity of TEUs handled	11%
		Ship load/discharge productivity	11%
		Equipment productivity	8%
Operational costs	24%	Infrastructure investment	29%
		Operational cost	27%
		Workforce cost	25%
Equipment and infrastructure	15%	Quantity of STS/cranes	22%
		Draft and length of the quay	21%
		Quantity of trucks	18%
Yard/warehouse capacity/occupation	13%	Yard occupation	28%
		Yard capacity	23%
		Container dwell time in the terminal	18%
Equipment maintenance	10%	Operational reliability	59%
		Equipment availability	21%
		Equipment reliability	20%

Source: Authors

6. CONCLUSION

In conclusion, this study aimed to identify the operational indicators of container terminals and determine/sort their relevance. With that in mind, we first found in the literature a set of 38 operational indicators, divided in 5 operational dimensions. By our survey instrument, the indicators were pairwise compared according to the preference of 7 seaport's managers, making possible to sort them using the AHP method.

As practical and managerial contributions we found that performance indicators (productivity) seem to be the most relevant for decision-makers. These indicators help in identifying areas that require improvement, reducing operational costs, increasing productivity and improving customer satisfaction. The second most important was 'operational cost'. By managing and reducing operational costs, container terminals can increase their profitability, maintain competitiveness in the market and provide cost-effective services to their customers. Hence, this research found that by tracking and analyzing the operational indicators, container terminals can make informed decisions and implement strategies to enhance their operations, especially focusing on the main relevant indicators to track.

The legacy of this research lies in the simplification of operational indicators for the management of seaport terminals, which can have a significant impact on the efficiency and competitiveness of these facilities. By signaling the main indicators, seaport managers can focus more on the critical factors for seaport operation such as volume of container, equipment productivity, infrastructure investment, yard occupation, and so on. This increased focus can lead to improved operational efficiency and ultimately better competitiveness for the seaport in regional and global market.

Besides the set of operational indicators, this research found the relative preference/weights of them. This information is useful for multi-criteria methods, mainly for the inter-criteria step. In this way, the results of this research could be applied in other decision problems, adding alternatives to be evaluated by the operational indicator criteria as seaport choice for customers and seaport call for ship carriers. With that in mind, the next step of this research regards the seaport choice problem, using the inter-criteria to sort or classify seaports alternatives in a delimited region, aiding customers to choose their logistic operator.

REFERENCES

Agência Nacional de Transportes Aquaviários. (2022). *Estatísticas*. Retrieved from https://web3.antaq.gov.br/ea/smartphone/pages/movContainer/movContainer.html

Agência Nacional dos Transportes Ferroviários. (2019). *The Brazilian Rail Freight Sector*. Retrieved from https://www.antf.org.br/informacoes-gerais/

Al-Eraqi, A., Mustafa, A., & Khader, A. (2010). An extended DEA windows analysis: Middle East and East African seaports. *Journal of Economic Studies*, 37(2), 208-218. https://doi.org/10.1108/01443581011043591

Bierwirth, C. & Meisel, F. (2010). A survey of berth allocation and quay crane scheduling problems in container terminals. *European Journal of Operational Research*, 202(3), 615-627. https://doi.org/10.1016/j.ejor.2009.05.031

Božičević, J., Lovrić, I., Bartulović, D., Steiner, S., Roso, V., & Škrinjar, J. (2021). Determining Optimal Dry Port Location for Seaport Rijeka Using AHP Decision-Making Methodology. *Sustainability*, 13, 6471. https://doi.org/10.3390/su13116471

Caggiani, L., Iannucci, G., Ottomanelli, M., Tangari, L., & Sassanelli, D. (2012). A fuzzy data meta training system for ranking hub container terminals. *European Transport*, 51(4), 1-16.

Cartenì, A. & Luca, S. (2012). Tactical and strategic planning for a container terminal: Modelling issues within a discrete event simulation approach. *Simulation Modelling Practice and Theory*, 21, 123-145. https://doi.org/10.1016/j.simpat.2011.10.005

Cruz, M., Ferreira, J., & Azevedo, S. (2013). Key factors of seaport competitiveness based on the stakeholder perspective: An Analytic Hierarchy Process (AHP) model. *Maritime Economics & Logistics*, 15, 416-443. https://doi.org/10.1057/mel.2013.14

Almeida, A., de. (2013). Processo de decisão nas organizações: construindo modelos de decisão multicritério. São Paulo: Atlas.

Drucker, P. (1954). *The practice of management*. New York: Harper & Row.

Fazi, S. & Roodbergen, K. (2018). Effects of demurrage and detention regimes on dry-port-based inland container transport. *Transp. Res. Part C*, 89, 1-18. https://doi.org/10.1016/j.trc.2018.01.012

Felicio, J., Caldeirinha, V., & Dionísio, A. (2014). The effect of port and container terminal characteristics on terminal performance. *Maritime Economics & Transportation*, 17, 493-514. https://doi.org/10.1057/mel.2014.33

Feng, M., Mangan, J., & Lalwani, C. (2012). Comparing port performance: Western European versus Eastern Asian ports. *International Journal of Physical Distribution & Logistics Management*, 42(5), 490-512. https://doi.org/10.1108/09600031211246537

Gonçalves, W., Rocha, A., Zatta, F., & Santos, D. (2021). Analytic hierarchy process (AHP) e a definição de atributos para apoio a tomada de decisão: uma análise bibliométrica. *Brazilian Journal od Production Engineering*, *7*(5), 103-118. https://doi.org/10.47456/bjpe.v7i5.36744

Ha, M. & Yang, Z. (2017). Comparative analysis of port performance indicators: Independency and interdependency. *Transportation Research Part A*, 103,264-278. https://doi.org/10.1016/j.tra.2017.06.013

Ha, M., Yang, Z., Notteboom, T., Ng, A., & Heo, M. (2017). Revisiting port performance measurement: A hybrid multi-stakeholder framework for the modelling of port performance indicators. *Transp. Res. Part E*, 103, 1–16. https://doi.org/10.1016/j.tre.2017.04.008

Haralambides, H. (2019). Gigantism in Container Shipping, Ports and Global Logistics: A Time-Lapse into the Future. *Maritime Economics and Logistics*, 21, 1-60. https://doi.org/10.1057/s41278-018-00116-0

Hauser, J. & Katz, G. (1998). Metrics: You Are What You Measure! *European Management Journal*, 16(5), 517-528. https://doi.org/10.1016/S0263-2373(98)00029-2

Huang, W., Wang, J., Kuo, T., & Wu, C. (2010). A Research on the Improvement Strategy on the Operation performance of Container Terminal. *Journal of the Eastern Asia Society for Transportation Studies*, 9, 2256-2271.

Instituto Brasileiro de Geografia e Estatística. (2020). *Projections of the population in Brazil*. Retrieved from https://www.ibge.gov.br/apps/populacao/projecao/

Jamain, R., Zakaria, R., & Satar, N. (2023). Asian port performance dimensions and analysis: a systematic literature review. *International Journal of Professional Business Review*, 8, 1-37. https://doi.org/10.26668/businessreview/2023.v8i1.1165

Jiang, J., Lee, L., Chew, E., & Gan, C. (2015). Port connectivity study: An analysis framework from container liner shipping network perspective. *Transportation Research Part E*, 73, 47-64. https://doi.org/10.1016/j.tre.2014.10.012

Júnior, R. (2008). *Hierarquização dos Indicadores de Desempenho da Qualidade Aplicada aos Terminais Portuários de Movimentação de Contêineres* (Dissertação de Mestrado). Instituto Militar de Engenharia, Rio de Janeiro, Brasil.

Kaplan, R. & Norton, D. (1992). The Balanced Scorecard: Measures that drive performance. *Harvard Business Review*, 5(3), 71-79.

Keeney, R. L. (1992). *Value-focused thinking: A path to creative decision making*. Cambridge: Harvard University Press.

Khaslavskaya, A. & Roso, V. (2020). Dry ports: research outcomes, trends, and future implications. *Maritime Economics and Logistics*, 22, 265-292. https://doi.org/10.1057/s41278-020-00152-9

Kim, B., Kim, G., & Kang, M. (2022). Study on Comparing the Performance of Fully Automated Container Terminals during the COVID-19 Pandemic. Sustainability, 14, 9415. https://doi.org/10.3390/su14159415

Lam, J. & Song, D. (2013). Seaport network performance measurement in the context of global freight supply chains. *Polish Maritime Research*, 20, 47-54. https://doi.org/10.2478/pomr-2013-0026

Lamii, N., Bentaleb, F., Fri, M., Mabrouki, C., & Semma, E. (2022). Use of DELPHI-AHP Method to Identify and Analyze Risks in Seaport Dry Port System. *Transactions on Maritime Science,* 11, 185-206. https://doi.org/10.7225/toms.v11.n01.w12

Largen, P., & Sharypova, K. (2013). Intermodal connectivity as a port performance indicator. *Research in Transportation Business & Management*, 8, 97-102. https://doi.org/10.1016/j.rtbm.2013.06.003

Lee, B. & Kim, K. (2013). Optimizing the yard layout in container terminals. *OR Spectrum*, *35*(2), 363-398. https://doi.org/10.1007/s00291-012-0298-z

Mahtani, U. & Garg, C. (2018). An analysis of key factors of financial distress in airline companies in India using fuzzy AHP framework. *Transportation Research Part A*, 117(C), 87-102. https://doi.org/10.1016/j.tra.2018.08.016

Mauboussin, M. (2012). The true measures of success. most companies use the wrong performance metrics. don't be one of them. *Harvard Business Review*, 90(10), 4-10.

Ministério do Desenvolvimento, Indústria, Comércio e Serviços. (2021). *Import and export general data*. Retrieved from http://comexstat.mdic.gov.br/pt/geral

Moya, J. & Valero, M. (2016). Port choice in container market: a literature review. *Transport Reviews*, 37, 300-321. https://doi.org/10.1080/01441647.2016.1231233

Munim, Z. & Schramm, H. (2018). The impacts of port infrastructure and logistics performance on economic growth: the mediating role of seaborne trade. *Journal of Shipping and Trade*, 3, 1-16. https://doi.org/10.1186/s41072-018-0027-0

Niedritis, A., Niedrite, L., & Kozmina, N. (2011). Performance measurement framework with formal indicator definitions. *Perspectives in Business Informatics Research*, 90, 44-58. https://doi.org/10.1007/978-3-642-24511-4_4

Nosal, K. & Solecka, K. (2014). Application of AHP Method for Multi-criteria Evaluation of Variants of the Integration of Urban Public Transport. *Transportation Research Procedia*, 3, 269-278. https://doi.org/10.1016/j.trpro.2014.10.006

Pun, K. & Nurse, A. (2010). Adopting quality management principles to revitalise the facilities maintenance practices at a port: A study in Trinidad and Tobago. *Asian Journal on Quality*, 11(3), 197-209. https://doi.org/10.1108/15982681011093961

Rashidi, H. & Tsang, E. (2013). Novel constraints satisfaction models for optimization problems in container terminals. *Applied Mathematical Modelling*, 37, 3601-3634. https://doi.org/10.1016/j.apm.2012.07.042

Rezaei, J. & Ortt, R. (2013). Supplier segmentation using fuzzy logic. *Industrial Marketing Management*, 42(4), 507-517. https://doi.org/10.1016/j.indmarman.2013.03.003

Rios, C. & Sousa, R. (2014). Cluster analysis of the competitiveness of container ports in Brazil.

Transportation Research Part A, 69, 423-431. https://doi.org/10.1016/j.tra.2014.09.005

Rodrigues, T., Mota, C., Pinto, D., & Araújo, A. (2021). *Identifying the factors engaged in customers' choice to operate through dry port or seaport* [Anais do International Joint Conference on Industrial Engineering and Operations Management]. IJCIEOM 2021, Rio de Janeiro, Brasil.

Saaty, T. (1987). The Analytic Hierarchy Process: What it is and how it is used. *Math Modelling*, 9(3), 161-176.

Saaty, T. (1994). *Fundamentals of Decision Making and Priority Theory with the Analytic Hierarchy Process*. 1 ed. Pittsburgh: Hardcopy.

Saaty, T. (2012). *Decision Making for Leaders: The Analytic Hierarchy Process for Decision in a Complex World*. 3 ed. Pittsburgh: RWS Publication.

Saaty, T. & Alexander, J. (2013). *Conflict Resolution: The Analytic Hierarchy Approach*. Pittsburgh: RWS Publication.

Simoni, M., Schiavone, F., Risitano, M., Leone, D., & Chen, J. (2022). Group-Specific Business Process Improvements via a Port Community System: The Case of Rotterdam. *Production Planning and Control*, 33(4), 371-385. https://doi.org/10.1080/09537287.2020.1824029

Subramian, N. & Ramanathan, R. (2012). A review of applications of Analytic Hierarchy Process in operations management. *Int. J. Production Economics*, 138, 215-241. https://doi.org/10.1016/j.ijpe.2012.03.036

Talley, M. & Ng, M. (2013). Maritime transport chain choice by carriers, port and shippers. *Int. J. Production Economics*, 142, 311-316. https://doi.org/10.1016/j.ijpe.2012.11.013

Tapia, R., Zárate, C., Esteban, A., Vieira, G., & Senna, L. (2014). Proposición y Evaluación de Indicadores de Movimiento de Carga para el puerto de Mar Del Plata. *Espacios*, 35(11), 9-21.

Tran, N., Haasis, H., & Buer, T. (2017). Container Shipping Route Design Incorporating the Costs of Shipping, Inland/Feeder Transport, Inventory and CO2 Emission. *Maritime Economics and Logistics*, 19(4), 667-694. https://doi.org/10.1057/mel.2016.11

Tranfield, D., Deyer, D., & Smart, P. (2003). Towards a Methodology for Developing Evidence-Informed Management Knowledge by Means of Systematic Review. British Journal of Management, 14(3), 207-222. https://doi.org/10.1111/1467-8551.00375

United Nations Conference on Trade and Development. (2019). *Review of maritime transport*. Retrieved from https://unctad.org/en/Pages/Publications/Review-of-Maritime-Transport-(Series).aspx

Vaidya, O. & Kumar, S. (2006). Analytic hierarchy process: An overview of applications. *European Journal of Operational Research*, 169, 1-29. https://doi.org/10.1016/j.ejor.2004.04.028

Yeo, G., Roe, M., & Dinwoodie, J. (2011). Measuring the competitiveness of container ports: logisticians' perspectives. *European Journal of Marketing*, 45(3), 455-470. https://doi.org/10.1108/03090561111107276