Logistic and Operation Management Research, Vol. 5 No.2 (2026) https://doi.org/10.31098/lomr.v5i2.4919

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Research Paper

Growing Cargo Volumes, Operational Efficiency and Port Capacity: A Comparative Analysis of Brazil's Waterway Sector (2024–2025)

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Received: September 08, 2026	Revised : October 11, 2026	Accepted : November 19, 2026	Online : November 20, 2026

Abstract

This study examines changes in cargo handling and operational performance in Brazil's waterway sector between 2024 and 2025, focusing on cargo profiles, vessel activity, operational productivity and port infrastructure requirements. A quantitative-descriptive approach supported by qualitative interpretation was adopted, using secondary data from the annual waterway performance reports published by the Brazilian National Waterway Transportation Agency (ANTAQ). The analysis compared cargo volumes and growth rates across the main cargo categories and examined available indicators of vessel activity and container handling. The findings show that total cargo handling increased by 6.1% in 2025, although growth varied across cargo segments. Containerized cargo recorded the highest growth among the main categories (7.2%), while general cargo showed a more modest increase (0.8%). The results also indicate that increased cargo volumes do not necessarily correspond to higher operational productivity, as greater cargo handling per vessel may coexist with longer operating times and lower hourly productivity. The study contributes to logistics and operations management by connecting sector-level cargo expansion with operational and infrastructure challenges. Its practical implications include the need for more comprehensive performance monitoring, differentiated operational planning and coordinated infrastructure investments. The findings provide a basis for further research on port performance and waterway logistics in emerging economies.

Keywords: *Waterway Transport, Port Performance, Logistics Management, Operational Productivity, Cargo Handling.*

INTRODUCTION

Waterway transportation plays an important role in international trade and supply chain management by connecting production areas, industrial centers and consumer markets. Ports are essential parts of this system because they support the movement of goods between maritime and inland transportation networks. Their performance directly affects logistics costs, cargo delivery times and the reliability of supply chains (Luca et al., 2025; Briones et al., 2025; Santos et al., 2026). As international trade expands and cargo flows become more complex, port managers face increasing pressure to improve operational planning, use available infrastructure more effectively and maintain reliable services. In this context, understanding the relationship between cargo growth and operational performance has become an important issue for logistics and operations management.

Brazil provides an interesting setting for examining these challenges. Its economy depends strongly on the transportation of agricultural products, minerals, fuels and manufactured goods, much of which moves through port facilities. The country also has an extensive coastline and a large network of inland waterways, creating different operational conditions across regions and types of terminals. According to the National Waterway Transportation Agency (ANTAQ, 2025), Brazilian port facilities handled approximately 1.32 billion tonnes of cargo in 2024. In 2025, this volume

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increased to 1.403 billion tonnes, representing annual growth of 6.1%. This expansion indicates stronger demand for waterway transportation and reinforces the importance of port infrastructure in supporting national and international logistics flows. However, higher cargo volumes also create additional demands on terminal capacity, equipment, labor, vessel scheduling and connections with inland transportation.

Previous research has examined port performance through different approaches, including productivity measurement, technical efficiency, benchmarking and the analysis of operational indicators. Traditional methods, such as Data Envelopment Analysis (DEA) and Stochastic Frontier Analysis (SFA), have been widely applied to compare the performance of ports and terminals based on available resources and cargo output. These approaches provide useful information about the relative efficiency of port facilities and help identify opportunities for better resource allocation. However, operational performance involves more than the relationship between inputs and outputs. It also includes service quality, vessel time in port, infrastructure utilization and the ability to coordinate different activities within the logistics chain.

Ha et al. (2017) contributed to this discussion by proposing a framework for measuring port performance from multiple stakeholder perspectives. Their study highlights the importance of considering different performance indicators and the relationships between them, rather than relying exclusively on traditional measures of operational efficiency. This approach is relevant because port operations involve several groups, including terminal operators, shipping companies, cargo owners and public authorities, whose expectations and performance priorities may differ. Similarly, Zhang et al. (2024), in a review of 301 studies on port efficiency, demonstrated that most previous research has concentrated on traditional efficiency measures and the perspectives of port authorities, managers and operators. The authors also identified the need for broader assessments that consider different stakeholders and the relationship between port service levels and economic performance.

Other studies have expanded the discussion by examining the functions and practical applications of performance indicators. Carvalho da Silva and Ensslin (2024), in a systematic review of 149 studies, found that port performance measurement has been widely used for benchmarking and monitoring. However, the use of performance indicators to support continuous improvement and predict operational results remains less developed. More recently, research has also highlighted the importance of integrating operational efficiency with infrastructure, logistics connectivity and sustainability. Alzate et al. (2024), for example, discussed how technological developments and environmental considerations are increasingly connected to the management of port operations. These contributions demonstrate that port performance should be understood as a combination of operational, organizational and logistics factors.

Despite these advances, an important limitation remains in the way port performance is examined. Many studies focus on individual terminals, specific operational processes or mathematical models designed to estimate relative efficiency. Although these methods provide valuable results, they do not always explain how changes in cargo demand relate to broader operational conditions across a national port system. In particular, comparisons between cargo growth, vessel activity, handling productivity and infrastructure utilization remain relevant for understanding the management challenges associated with expanding waterway transportation. Furthermore, the use of statistical information published by national regulatory agencies offers an opportunity to examine these relationships in an applied context, especially in countries where port facilities have different levels of specialization and infrastructure development.

This study addresses this issue by comparing statistical information from the 2024 and 2025 editions of ANTAQ's Waterway Performance Yearbook. Rather than treating the increase in cargo handling as sufficient evidence of improved performance, the analysis considers the relationship

between cargo volumes, cargo profiles, vessel activity, container handling indicators and port infrastructure utilization. This perspective is important because an increase in throughput may occur alongside longer operating times, lower handling productivity or greater pressure on available terminal capacity. For example, ANTAQ's 2024 report shows that average container cargo per vessel increased from 768 to 855 units between 2023 and 2024, while average operational productivity decreased from 52.2 to 46.3 units per hour and average operating time increased from 14.8 to 18.6 hours. These indicators illustrate why cargo growth and operational performance should be examined together.

The scientific contribution of this research lies in bringing these dimensions together through a comparative analysis of official national statistics, with particular attention to their implications for logistics and operations management. The study does not aim to estimate the technical efficiency of individual terminals or establish causal relationships between cargo growth and operational productivity. Instead, it seeks to identify patterns, differences and management challenges that may not be evident when cargo volumes are examined separately. By combining demand-related indicators with available measures of operational activity and infrastructure utilization, the research provides a broader understanding of how the Brazilian waterway sector has responded to changes in cargo flows. It also offers practical insights into capacity planning, resource allocation, vessel scheduling and the coordination of port operations with inland logistics networks. Therefore, this study aims to analyze changes in cargo handling and operational performance in Brazil's waterway sector between 2024 and 2025, identifying the main challenges associated with logistics management, operational productivity and port infrastructure utilization. Specifically, it compares cargo volumes and cargo profiles, examines available indicators of vessel activity and container handling, and discusses the implications of these changes for port capacity and operations management.

LITERATURE REVIEW

Port performance is a multidimensional concept that reflects the ability of port facilities to handle cargo, allocate operational resources, provide reliable services, and support the movement of goods through logistics networks. From an operations management perspective, performance should not be understood exclusively in terms of cargo volume or financial results. It also involves the relationship between the resources employed, the time required to complete operations, and the infrastructure available to accommodate transport demand. Hung et al. (2010) and Wanke (2013) provide a relevant foundation for examining port efficiency and resource utilization, particularly when differences in operational conditions affect the comparability of port facilities. These considerations support an integrated interpretation of port performance in which cargo movement, operational productivity, and infrastructure constraints represent complementary analytical dimensions.

Cargo throughput refers to the quantity of goods handled by a port or terminal during a defined period, generally expressed in tonnes or twenty-foot equivalent units (TEUs). It is an important indicator of transport demand and operational scale, but it does not independently demonstrate how efficiently resources are employed. A terminal may increase its annual throughput by receiving additional vessels, extending operating hours, or processing larger cargo volumes per call without necessarily improving the speed of cargo handling. Operational productivity, in contrast, measures the relationship between output and the resources or time required to generate it. In port operations, common productivity measures include tonnes handled per hour, containers handled per hour, and cargo handled per vessel call. These indicators provide different perspectives on operational activity and should be interpreted according to cargo characteristics, vessel dimensions, equipment availability, and terminal organization. The

distinction is particularly relevant to the present research because changes in total cargo handling may occur independently of improvements in hourly productivity.

Capacity utilization introduces another dimension of performance assessment. It represents the extent to which available infrastructure or operational resources are used relative to their effective capacity during a given period. In port systems, capacity depends on several interconnected components, including berth availability, handling equipment, storage facilities, access channels, and connections with inland transport networks. Effective capacity may therefore differ from nominal or designed capacity because of maintenance requirements, operating schedules, navigation restrictions, and coordination between activities. Higher utilization can indicate more intensive use of existing infrastructure, but it may also increase congestion and reduce operational flexibility when demand approaches the limits of available resources. Vilarinho et al. (2024) provides a relevant contribution to the discussion of operational and infrastructure constraints, while Abramowicz-Gerigk and Burciu (2016), Petru and Krivda (2021), and Rodrigue (2024) offer complementary perspectives for understanding the relationship between transport infrastructure, operational conditions, and logistics performance.

These concepts are connected through the interaction between demand, operational processes, and infrastructure availability. Throughput represents the volume processed, productivity indicates the rate at which operations are performed, and capacity utilization describes the pressure placed on available resources. Port performance encompasses these dimensions while also considering service reliability and logistics coordination. For example, an increase in throughput accompanied by stable operating time may suggest an improvement in operational organization, whereas similar growth associated with longer vessel stays may indicate additional pressure on handling systems. Nevertheless, such relationships require careful interpretation because differences in vessel size, cargo composition, and terminal specialization can influence the observed indicators. This conceptual distinction is essential for avoiding the assumption that cargo growth automatically represents improved efficiency.

The empirical literature offers different approaches to examining these relationships. Studies based on Data Envelopment Analysis and Stochastic Frontier Analysis have contributed to understanding how ports transform infrastructure, equipment, and labor into operational outputs. However, efficiency scores are relative measures that depend on the selected variables and the characteristics of the facilities included in the analysis. Zhang et al. (2024) identify the predominance of traditional efficiency approaches in port research, while de Souza et al. (2026) contributes to the broader discussion of quantitative performance assessment. These approaches are valuable for benchmarking, but their results should not be interpreted as direct substitutes for operational indicators such as handling rates, vessel operating time, or infrastructure utilization. Consequently, a descriptive assessment of cargo movement and operational activity can provide complementary evidence without requiring the estimation of technical efficiency scores.

Brazilian port performance presents additional analytical challenges because the national system includes facilities with different cargo specializations, infrastructure arrangements, and geographic conditions. Wanke (2013) is particularly relevant to this context because the analysis of Brazilian port efficiency highlights the importance of considering operational characteristics when comparing facilities. Differences between ports serving agricultural exports, mineral commodities, liquid bulk, and containerized trade can affect both the resources required and the interpretation of performance indicators. A port specializing in solid bulk cannot be evaluated using exactly the same operational expectations as a container terminal, since handling technologies, storage requirements, and vessel operations differ substantially. Accordingly, comparisons across the Brazilian port system require attention to cargo composition and operational specialization rather than reliance on aggregate throughput alone.

The relationship between maritime ports and inland waterway transportation further extends this discussion. Inland navigation operates within a logistics environment in which waterway conditions, vessel characteristics, terminal accessibility, and connections with road and rail infrastructure influence service performance. Unlike an assessment restricted to seaport terminals, the evaluation of inland waterway operations must consider the continuity of transport activities across different sections of the logistics network. Navigation restrictions, seasonal variations in water levels, and limitations in terminal infrastructure may affect the reliability and effective capacity of these services. Rodrigue (2024) provides a broader transport geography perspective for understanding the integration of transport modes, while the operational considerations discussed by Abramowicz-Gerigk and Burciu (2016) and Petru and Krivda (2021) help frame the importance of infrastructure and transport conditions. These contributions support the interpretation of inland navigation as an interconnected logistics activity rather than an isolated cargo handling operation.

In the Brazilian context, official statistics published by the National Waterway Transportation Agency provide an empirical basis for examining the development of maritime and inland waterway transport. ANTAQ (2025, 2026) documents cargo movement across different categories and presents selected indicators of vessel activity and operational productivity. These records are relevant because they permit the examination of sector-wide changes using a consistent institutional source. Nevertheless, aggregate statistics also present analytical limitations. National cargo growth may reflect changes in commodity demand, vessel characteristics, terminal activity, or the distribution of cargo between facilities. It does not necessarily indicate that individual ports have increased their productivity or that infrastructure utilization has improved. Similarly, growth in inland navigation should be assessed in relation to the availability and compatibility of infrastructure, rather than interpreted as evidence of operational efficiency by itself.

An additional issue concerns the managerial interpretation of performance indicators. Carvalho da Silva and Ensslin (2024) identify benchmarking and performance monitoring as important applications of port measurement systems, while also drawing attention to opportunities for improving their practical use in management. From this perspective, the value of operational indicators depends not only on their measurement but also on their ability to reveal potential constraints and support decisions. For instance, monitoring throughput alongside vessel activity and hourly handling productivity may help distinguish between expansion resulting from additional operational demand and expansion associated with more effective resource use. The integration of such information can support equipment planning, berth allocation, storage management, and infrastructure investment decisions.

Although the literature provides substantial knowledge about port efficiency and performance measurement, a distinction remains between studies focused on individual facilities and analyses of operational changes across an entire national waterway sector. The available approaches offer valuable evidence about relative efficiency, infrastructure requirements, and logistics organization, but they do not always connect changes in cargo composition with vessel activity, handling productivity, and capacity-related implications within the same analytical framework. This distinction becomes especially important when comparing consecutive reporting periods, since an increase in demand may create different operational consequences depending on the cargo category and available infrastructure. The present study therefore adopts a multidimensional conceptual perspective to examine Brazil's waterway sector between 2024 and 2025. Its analytical framework considers cargo throughput as an indicator of transport activity, operational productivity as a measure of handling performance, and infrastructure utilization as a capacity-related dimension that must be interpreted according to the information available. Vessel activity and operating time provide additional evidence for understanding these relationships.

Rather than assuming that greater cargo movement corresponds to improved efficiency, the research investigates how changes in demand and cargo composition relate to reported operational conditions. This approach contributes to the literature by connecting established performance concepts with official Brazilian waterway statistics, while recognizing the limitations of aggregate data and the need for further terminal-level investigations.

RESEARCH METHOD

The adoption of a descriptive comparative approach allows the systematic examination of changes in operational indicators across defined reporting periods. According to Johnston (2014), secondary data analysis requires careful consideration of data sources, measurement consistency, and suitability for the research objectives. Similarly, Kothari (2004) emphasizes the importance of structured quantitative procedures for identifying variations and patterns in observed data. In this study, the comparison of official waterway statistics provides a basis for assessing changes in cargo handling and operational conditions without assuming causal relationships between the selected indicators.

This study adopts a quantitative-descriptive approach supported by qualitative interpretation to examine changes in Brazil's waterway sector between 2024 and 2025. The research is based on secondary data published by the Brazilian National Waterway Transportation Agency (ANTAQ), specifically the Desempenho Aquaviário 2024 and Desempenho Aquaviário 2025 reports (ANTAQ, 2025, 2026). These reports provide official information on cargo handling, cargo categories, vessel activity and selected operational indicators. Their use allows the analysis to be based on standardized institutional statistics rather than estimates from individual companies. The research was conducted in four stages. The two reports were examined to identify data relevant to cargo movement and port operations. The selected variables included total cargo handled, cargo volumes by category, vessel calls, average cargo handled per vessel, container handling productivity and average operating time. Information on inland waterway transport and port infrastructure utilization was also considered when available and relevant to the research objectives.

The data were organized into comparative tables and classified according to their measurement units, reference periods and operational definitions. The comparison focused primarily on indicators reported for both years under sufficiently compatible conditions. Indicators available in only one report, or presented with different definitions or scopes, were treated as complementary evidence rather than as direct measures of annual change. This procedure was adopted to avoid misleading comparisons and unsupported conclusions about changes in operational performance. Changes in cargo volumes were calculated using absolute and percentage variations. To ensure consistency and reproducibility, the selected indicators were classified according to their definitions, measurement units, reference years, and data sources. Two analytical categories were established. The first included indicators available for both 2024 and 2025 under comparable measurement conditions, allowing direct annual comparisons. The second comprised indicators reported for different periods or operational classifications, which were used exclusively as complementary evidence. This distinction was particularly relevant for vessel activity, container handling productivity, and operating time, since the available reports did not consistently present equivalent observations for both years. Table 1 summarizes the selected indicators and their respective analytical classifications.

Table 1. Description and comparability of selected research indicators

Indicator	Definition and unit	Reference years	Source	Analytical use
Total cargo throughput	Total cargo handled; tonnes	2024–2025	ANTAQ (2025, 2026)	Direct
Solid bulk cargo	Solid bulk volume; tonnes	2024–2025	ANTAQ (2025, 2026)	Direct
Liquid bulk cargo	Liquid bulk volume; tonnes	2024–2025	ANTAQ (2025, 2026)	Direct
Containerized cargo	Containerized cargo volume; tonnes	2024–2025	ANTAQ (2025, 2026)	Direct
General cargo	General cargo volume; tonnes	2024–2025	ANTAQ (2025, 2026)	Direct
Container vessel calls	Number of vessel calls	2023–2024	ANTAQ (2025)	Complementary
Cargo per vessel	Average containers handled per vessel; units/vessel	2023–2024	ANTAQ (2025)	Complementary
Handling productivity	Average containers handled per operating hour; units/hour	2023–2024	ANTAQ (2025)	Complementary
Operating time	Average vessel operating time; hours	2023–2024	ANTAQ (2025)	Complementary
Productivity by vessel size	Container handling rate; TEU/hour	2025	ANTAQ (2026)	Complementary
Inland navigation	Reported cargo handling growth; %	2025 versus 2024	ANTAQ (2026)	Direct growth rate
Berth occupancy	Occupied berth time relative to available time; %	Not established	Selected reports	Not measured
Storage utilization	Occupied storage relative to effective capacity; %	Not established	Selected reports	Not measured
Equipment utilization	Equipment operating time relative to available time; %	Not established	Selected reports	Not measured
Terminal capacity utilization	Throughput relative to installed or effective capacity; %	Not established	Selected reports	Not measured

Source: Prepared by the authors based on ANTAQ (2025, 2026) and the indicators reported in the manuscript. The unavailable indicators were not calculated; their absence from the analytical dataset does not establish that ANTAQ never publishes them. Absolute variation was obtained by subtracting the 2024 value from the corresponding 2025 value:

$$\Delta V = V_{2025} - V_{2024} \quad (01)$$

Percentage variation was calculated as follows:

$$\text{Variation } (\%) = [(V_{2025} - V_{2024}) / V_{2024}] \times 100 \quad (02)$$

Where (V_{2025}) represents the value reported for 2025 and (V_{2024}) represents the corresponding value for 2024. These calculations were applied only when the indicators had comparable definitions and measurement units.

The final analytical stage involved interpreting the descriptive results in relation to established concepts of port performance, operational productivity, and logistics management. This interpretation was conducted by examining the consistency between observed changes in cargo throughput and the complementary information available on vessel activity, handling rates, operating time, and infrastructure requirements. Differences among cargo categories were also considered because each segment presents specific operational characteristics. The interpretation was supported by the existing literature and official institutional information, without employing interviews, qualitative coding, or other independent qualitative research procedures. Accordingly, the study remains quantitative and descriptive, while contextual discussion is used to explain the operational relevance of the statistical findings.

Research Procedures

The research was conducted through five sequential stages, designed to ensure the systematic collection, organization, comparison and interpretation of the data.

1) Stage 1 – Identification and selection of data sources. The first stage consisted of identifying the official statistical sources used in the research. Two annual reports published by the Brazilian National Waterway Transportation Agency (ANTAQ) were selected: Desempenho Aquaviário 2024 and Desempenho Aquaviário 2025. These documents were chosen because they provide consolidated information on cargo handling, vessel activity and selected operational characteristics of Brazil's waterway sector.
2) Stage 2 – Data extraction and classification. In the second stage, relevant information was extracted from the reports and organized into a structured database. The variables were classified into four analytical groups: (i) total cargo handling; (ii) cargo volumes by category, including solid bulk, liquid bulk, containerized cargo and general cargo; (iii) vessel activity and container handling indicators; and (iv) information related to inland navigation and port infrastructure utilization. Each variable was recorded together with its measurement unit, reference year and corresponding source.
3) Stage 3 – Data standardization and comparability assessment. The third stage involved checking the consistency of the extracted information. The indicators were examined according to their definitions, measurement units, reference periods and levels of aggregation. Whenever differences in reporting criteria or indicator availability were identified, the variables were treated separately. This procedure prevented the direct comparison of indicators that did not share sufficiently compatible measurement conditions.
4) Stage 4 – Quantitative analysis and comparative assessment. In the fourth stage, absolute and percentage variations were calculated for comparable indicators between 2024 and 2025. The results were presented through tables and graphical representations to facilitate the identification of growth patterns and differences among cargo categories. Indicators available for only one reporting period were used as complementary evidence to support the operational analysis, without being interpreted as evidence of annual improvement or deterioration.
5) Stage 5 – Interpretation of findings and identification of managerial implications. Finally, the quantitative results were interpreted in relation to the literature on port performance,

logistics management and operations management. The analysis focused on the relationship between cargo expansion, vessel activity, operational productivity and infrastructure requirements. Particular attention was given to the distinction between increased cargo throughput and improved operational performance. Based on this interpretation, the study identified relevant challenges for port authorities, terminal operators and public policymakers, as well as opportunities for further academic research.

These five stages provided a structured procedure for addressing the research objective. By combining official statistical information, descriptive calculations and critical interpretation, the study developed a comparative assessment of Brazil's waterway sector while respecting the limitations of the available data.

FINDINGS AND DISCUSSION

Growth in cargo handling and changes in cargo profile

Brazil's waterway sector recorded a significant increase in cargo handling between 2024 and 2025. According to ANTAQ (2025, 2026), total cargo volume increased from approximately 1.32 billion tonnes in 2024 to 1.4 billion tonnes in 2025, representing annual growth of 6.1%. This result indicates an expansion in the demand for waterway transport and reinforces the importance of port infrastructure in supporting national and international trade. The growth was observed across the main cargo categories, although at different rates. In 2025, solid bulk reached 839.7 million tonnes, an increase of 6.3%, while liquid bulk reached 333 million tonnes, growing by 6.1%. Containerized cargo increased by 7.2%, reaching 164.6 million tonnes, and general cargo recorded a more moderate increase of 0.8%, reaching 65.8 million tonnes (ANTAQ, 2026).

Figure 1 presents the growth rates in cargo handling across the main cargo categories in Brazil in 2025. General cargo showed a more modest increase of 0.8%. Compared with the overall sector growth of 6.1%, these results indicate that the expansion was concentrated in specific cargo segments rather than being evenly distributed. From an operations management perspective, this variation highlights the need for differentiated planning strategies, considering the equipment, storage capacity and handling processes required by each cargo type. The findings reinforce that aggregate growth figures alone are insufficient to assess operational performance, since each category creates different demands on port infrastructure and logistics activities.

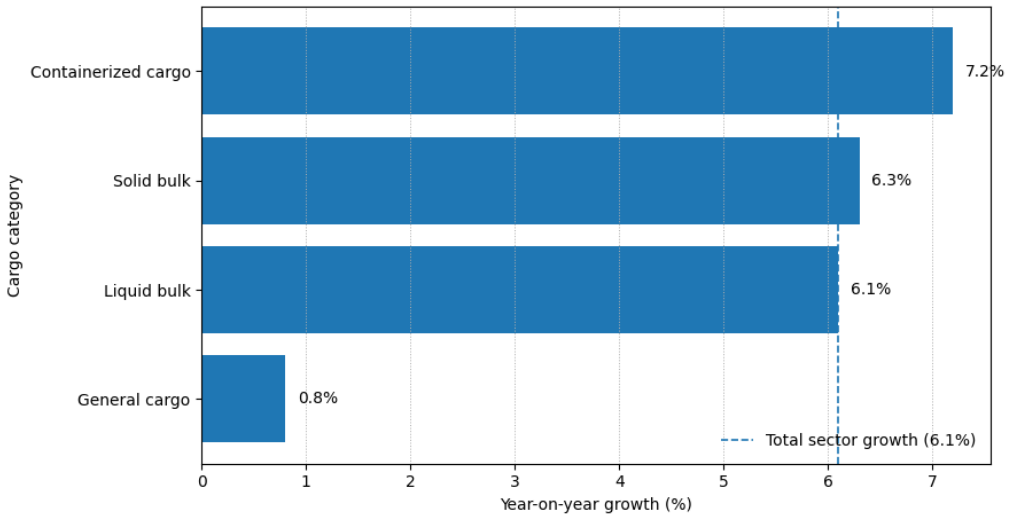


Figure 1. Cargo handling growth by category in Brazil, 2025
Source: Prepared by the authors based on ANTAQ (2026).

These differences are relevant from an operations management perspective. Solid and liquid bulk operations depend on specific handling systems, storage facilities and loading equipment. Container operations, in turn, require coordination among terminals, vessels, storage yards and inland transport. Therefore, the expansion of total cargo volume does not create the same operational requirements across all port facilities. The results suggest that planning decisions should consider the composition of cargo growth rather than relying exclusively on aggregate throughput.

Vessel activity and operational productivity

The available operational indicators provide additional evidence about the relationship between cargo growth and port performance. The 2024 ANTAQ report presented an increase in container vessel calls from 8,912 in 2023 to 9,447 in 2024, corresponding to growth of 6.0%. Average container cargo handled per vessel also increased, from 768 to 855 units, while average operational productivity decreased from 52.2 to 46.3 units per hour. Average operating time increased from 14.8 to 18.6 hours (ANTAQ, 2025). Although these indicators refer to the 2023–2024 period and therefore cannot be interpreted as a direct comparison between 2024 and 2025, they reveal an important operational relationship. A higher volume handled per vessel may occur alongside lower hourly productivity and longer operating times. This means that greater cargo handling does not automatically translate into faster or more efficient port operations. The 2025 report provides another relevant observation: vessels with capacity above 14,000 TEU recorded average productivity of 69 TEU per hour, compared with 23 TEU per hour for vessels below 2,500 TEU (ANTAQ, 2026). This difference indicates that vessel size is an important factor when interpreting container handling productivity. However, these figures refer to different vessel capacity groups and should not be directly compared with the national average reported for the previous period. They also suggest that terminal planning must consider the compatibility between vessel dimensions, equipment capacity and available infrastructure.

Expansion of inland navigation and infrastructure requirements

One of the most relevant findings in 2025 was the 19.7% growth in inland navigation cargo handling. This increase was considerably higher than the overall sector growth of 6.1% (ANTAQ, 2026). It highlights the growing importance of inland waterways within Brazil's logistics system and raises questions about the capacity of terminals, waterways and supporting infrastructure to accommodate additional demand. From a management perspective, this expansion requires coordination between waterway conditions, vessel availability, terminal operations and connections with other transport modes. The performance of inland navigation depends not only on cargo handling capacity but also on the reliability of routes and the integration of ports with production and consumption areas. Consequently, investments in terminals should be considered together with improvements in access infrastructure and logistics coordination.

Implications for port logistics and comparison with previous studies

The findings support the argument that port performance should be evaluated through multiple indicators rather than cargo volume alone. This is consistent with Ha et al. (2017), who emphasize the importance of considering different stakeholders and dimensions of port performance. The present analysis adds a sector-level perspective by relating cargo expansion to available indicators of vessel activity, handling productivity and infrastructure requirements. The results also complement Zhang et al. (2024), whose review identified the predominance of traditional efficiency measures and analyses focused on port authorities and operators. Instead of

estimating technical efficiency through DEA or SFA, this study examines the operational implications of changes in cargo demand using official national statistics. This approach does not replace terminal-level efficiency studies; it provides a broader view of the conditions under which port operations and logistics systems must respond to increasing demand.

Furthermore, the findings are relevant to the discussion by Carvalho da Silva and Ensslin (2024) regarding the use of performance indicators as management tools. The comparison demonstrates that indicators can help identify issues that aggregate throughput figures may conceal. For example, the coexistence of higher cargo volumes per vessel, lower hourly productivity and longer operating times in the 2023–2024 container indicators shows why managers should monitor several operational dimensions simultaneously.

Overall, the results indicate that Brazil's waterway sector is expanding, but this growth also increases the need for coordinated operational planning. Port managers and public authorities should monitor cargo profiles, vessel activity, handling productivity and infrastructure utilization together. Such an approach can support decisions on equipment, storage capacity, workforce allocation, vessel scheduling and connections with road, rail and inland waterway networks. The evidence does not establish that the sector's overall efficiency improved or declined between 2024 and 2025; rather, it identifies operational challenges that deserve attention as cargo demand continues to grow.

Practical and Academic Contributions

This study offers practical contributions to the management of Brazil's waterway transport sector by providing an integrated perspective on cargo growth, operational performance and infrastructure requirements. The findings can support port authorities, terminal operators and public policymakers in identifying the operational challenges associated with increasing cargo demand. By showing that cargo growth does not necessarily correspond to improved operational productivity, the study highlights the importance of monitoring a broader set of performance indicators, including cargo volume, vessel activity, handling productivity and operating time.

From a managerial perspective, the results can contribute to more informed decisions regarding infrastructure planning, equipment capacity, storage management, workforce allocation and vessel scheduling. The differences observed among cargo categories also indicate that operational strategies should be adapted to the specific requirements of solid bulk, liquid bulk, containerized cargo and general cargo. Furthermore, the expansion of inland navigation reinforces the need to improve coordination between port facilities, waterway infrastructure and connections with road and rail transport. These insights may help decision-makers prioritize investments and improve the coordination of logistics activities, although the study does not directly evaluate the effectiveness of specific management interventions.

The academic contribution lies in connecting cargo demand expansion with operational and infrastructure management at the national sector level. While much of the existing literature focuses on individual ports, terminal-level performance or technical efficiency measurement, this study provides a complementary approach based on the comparative analysis of official sector statistics. It brings together different dimensions of port operations and demonstrates the importance of interpreting throughput data alongside other operational indicators. The study also contributes to the discussion on port performance measurement by emphasizing the distinction between sector growth and operational efficiency. This distinction is relevant for future research because an increase in cargo handling may create additional pressure on infrastructure and operational resources without necessarily improving service productivity. By identifying this analytical issue in the Brazilian context, the research provides a basis for further investigations

using longer time series, terminal-level data and more advanced performance evaluation methods.

Overall, the study contributes to both practice and academic research by offering a structured perspective on the challenges associated with the expansion of waterway transport. It supports the development of more comprehensive performance monitoring practices while providing an empirical starting point for future studies on port logistics, infrastructure utilization and operations management in emerging economies.

CONCLUSIONS

This study analyzed changes in cargo handling and operational performance in Brazil's waterway sector between 2024 and 2025, focusing on cargo profiles, vessel activity, operational productivity and port infrastructure requirements. The findings show that the sector experienced significant growth, with total cargo handling increasing by 6.1% in 2025, according to ANTAQ. However, this expansion was not uniform across cargo categories, highlighting the different operational demands faced by port terminals and logistics operators.

The results also demonstrate that cargo growth should not be interpreted as direct evidence of improved operational performance. The available container indicators show that higher average cargo volumes per vessel can coexist with lower hourly productivity and longer operating times. In addition, differences in productivity among vessel capacity groups indicate that vessel characteristics and terminal infrastructure must be considered when evaluating operational results. The strong growth in inland navigation further emphasizes the importance of infrastructure planning and integration between waterway transport and other logistics modes.

The main contribution of this study is its integrated assessment of cargo expansion and operational management challenges at the national sector level. While previous research has frequently focused on individual ports, terminals or technical efficiency measurements, this study brings together different operational dimensions using official Brazilian waterway statistics. It therefore provides a broader understanding of how increasing transport demand can affect port operations and infrastructure requirements.

From a managerial perspective, the findings indicate that port authorities and terminal operators should not rely exclusively on cargo throughput when monitoring performance. They should also consider vessel handling productivity, operating time, cargo characteristics, infrastructure utilization and connections with other transport modes. These indicators can support decisions regarding equipment capacity, terminal organization, workforce allocation, vessel scheduling and infrastructure investment.

In conclusion, the expansion of Brazil's waterway sector represents an important opportunity for strengthening the country's logistics system. However, sustaining this growth requires coordinated planning, continuous performance monitoring and investments aligned with the operational characteristics of different cargo segments. The study reinforces the importance of evaluating port development through a combination of demand, operational and infrastructure indicators rather than through cargo volume alone.

LIMITATION & FURTHER RESEARCH

This study has limitations that should be considered when interpreting its findings. First, the analysis is based exclusively on secondary data published by ANTAQ. Consequently, the results depend on the availability, accuracy and reporting criteria adopted by the agency. Second, the two annual reports do not provide exactly the same set of operational indicators or necessarily use identical levels of aggregation. This restricts the possibility of establishing direct comparisons across all dimensions between 2024 and 2025. Another limitation concerns the level of analysis. The study examines the Brazilian waterway sector as a whole and does not investigate the

operational performance of individual ports or terminals. Therefore, differences in local infrastructure, management practices, equipment availability and operational conditions cannot be fully identified. Furthermore, the descriptive approach allows the identification of patterns and relationships in the reported data but does not establish causal relationships between cargo growth, infrastructure utilization and operational productivity.

Future research could address these limitations in several ways. First, studies could develop longer time-series analyses to examine whether the observed growth represents a sustained trend and how it relates to changes in operational indicators over time. Second, terminal-level investigations could compare productivity, vessel turnaround time, infrastructure utilization and resource allocation across different port facilities. Third, the application of methods such as Data Envelopment Analysis (DEA) or Stochastic Frontier Analysis (SFA), using consistent input and output data, could provide more detailed assessments of technical efficiency.

Further studies could also investigate the relationship between port operations and hinterland connectivity, particularly the integration of waterway, road and rail transport. Finally, research combining quantitative operational data with interviews involving port authorities, terminal operators and logistics users could provide a more comprehensive understanding of the managerial and institutional factors influencing port performance in Brazil. These research directions would contribute to a more detailed understanding of the relationship between cargo expansion, operational capacity and logistics performance, supporting evidence-based decisions for the development of Brazil's waterway transport system.

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