

Analysis of the relationship among administrative expenditures, workforce, and costs associated with Maritime Authority activities

Análise da relação entre gastos administrativos, força de trabalho e custos atrelados às atividades de Autoridade Marítima

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Autoridade Marítima. A metodologia utilizada teve uma abordagem quantitativa, por meio de um modelo de regressão linear múltipla para avaliar a influência das variáveis explicativas, como os gastos administrativos (ADM) e a força de trabalho (FT), nos custos atrelados aos Serviços de Portos e Costas (SPC). Como resultado, a análise do modelo demonstra que o custo atrelado aos serviços de portos e costas possui correlações positivas de 0.88 e 0.81 com os gastos administrativos e a força de trabalho, respectivamente. Os resultados demonstram, portanto, que a variável SPC das organizações militares (OM) da rede Capitânicas, Delegacias e Agências (CDA) da Marinha do Brasil (MB), está fortemente correlacionada com os gastos voltados à estrutura administrativa das OM, bem como o número de militares empregados para o desempenho de suas atividades, oferecendo uma compreensão clara para o planejamento e a gestão de recursos no contexto militar. Sugere-se melhorias na alocação de recursos e recomenda-se o uso de metodologias quantitativas para otimizar a gestão das OM.

Palavras-Chave: Gestão de Custos. Regressão linear. Marinha do Brasil. Gastos administrativos. Força de trabalho.

ODS4 – Educação e qualidade.

Linha de pesquisa: Controladoria com ênfase em Gestão em Organizações Públicas.

ABSTRACT

The aim of this article is to analyze the relationship between administrative expenses, the workforce and the costs associated with Maritime Authority activities. The methodology used had a quantitative approach, using a multiple linear regression model to assess the influence of explanatory variables, such as administrative expenses (ADM) and workforce (FT), on the costs associated with Ports and Coasts Services (SPC). As a result, the analysis of the model shows that the cost of port and coastal services has positive correlations of 0.88 and 0.81 with administrative expenses and the workforce, respectively. This shows that the SPC variable of the military organizations (OM) in the Brazilian Navy's (MB) Captaincies, Delegations and Agencies (CDA) network is strongly correlated with spending on the OM's administrative structure, as well as the number of military personnel employed to carry out its activities, which provides a clear understanding for planning and managing resources in the military context. It suggests improvements in resource allocation and recommends the use of quantitative methodologies to optimize OM management.

Keywords: Cost Management; Linear Regression; Brazilian Navy; Administrative Expenditures; Workforce.

RESUMO

Este artigo objetiva analisar a relação entre os gastos administrativos, a força de trabalho e os custos atrelados às atividades de

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1. INTRODUCTION

In a context of fiscal constraint, innovative solutions become necessary for the monitoring, management, and control of public expenditures (Freitas et al., 2021). Resource management in the public sector is increasingly challenging, particularly due to budgetary constraints and the need—driven by an increasingly globalized society—for transparency and efficiency (Inglot, 2024). In this regard, according to Alonso (2022), the implementation of effective cost control and planning systems not only enhances efficiency but also ensures greater transparency and accountability, positively influencing the operational capacity of agencies and institutions, thereby enabling the effective allocation of human and financial resources.

The need to control and minimize costs, mitigate risks, maximize outcomes, and promote the sustainability of activities through the proper management of financial, material, and human resources constitutes a fundamental objective for achieving the strategic goals established by institutions, particularly within a context of public expenditure control and the pursuit of transparency in the use of such resources (Alonso, 2022).

In this context, the Brazilian Navy (MB), through the Military Organizations (MOs) within the network of Harbormasters' Offices, Delegations, and Agencies (CDA), performs—subsidiarily to its constitutional functions—the role of Brazilian Maritime Authority (BMA) (Law No. 9,537, 1997). In this capacity, it acts to ensure the protection of human life, the safety of waterborne traffic, and the protection of marine resources by conducting inspections, regulatory enforcement actions, and naval surveys, among other objectives established under the Navy's Strategic Planning for the 2020–2040 period (PEM2040, 2020).

Considering the strategic importance of these operations, as well as the allocation—pursuant to the Annual Budget Law—of approximately BRL 30 billion to the Navy Command (Law No. 14,488, 2024), combined with the need for public expenditure control and the pursuit of efficiency, the implementation of management accounting systems enables the Naval Force to identify non-value-adding activities, eliminate redundant processes, and strategically reallocate resources, personnel, and activities (Garrison et al., 2013). According to Freitas et al. (2021), given the need to measure efficiency in the public sector, workforce management becomes a central element for the effectiveness of government services. The authors further emphasize the importance of monitoring and controlling administrative expenditures in order to prevent waste and ensure that such costs do not compromise the allocation of resources to core (mission-oriented) activities.

Accordingly, the Federal Accounting Council (CFC) issued the Brazilian Public Sector Accounting Standard 34 – Cost in the Public Sector (NBC TSP 34), which establishes guidelines for the implementation of procedures for the recognition and measurement of costs, with the aim of enhancing governance and transparency in government expenditures in order to achieve strategic objectives (CFC, 2021).

In this context, the following research problem is proposed: how do administrative expenditures and workforce allocation affect the costs associated with Maritime Authority activities? In order to analyze the relationship between administrative expenditures, workforce allocation, and the costs associated with Maritime Authority activities, the following objectives were established

specific objectives: (i) to assess the correlation between administrative expenditures and the costs associated with ports and coastal activities; (ii) to assess the correlation between workforce allocation and the costs associated with ports and coastal activities; and (iii) to develop a predictive cost model for the Military Organizations (MOs) based on data on administrative expenditures, workforce allocation, and ports and coastal activity costs.

The study is justified as it addresses a relevant topic, given that social and technological transformations in planning, control, and evaluation instruments directly influence the outcomes of public resource allocation and, for this reason, must be explored in order to contribute to the academic field (Alonso, 2022).

Additionally, the present study responds to societal demands for greater transparency and accountability in the use of public resources (Santos Júnior et al., 2023) and is aligned with the principles of Stakeholder Theory, which posits that organizations should meet the expectations of different stakeholder groups, including society as a whole (Góes et al., 2021).

Thus, the analysis may contribute to improving budget planning and cost management within the Military Organizations (MOs) of the Brazilian Navy. The study aims to provide inputs for enhancing cost management in the MOs of the CDA network, based on quantitative analyses that enable the prediction and control of the main variables affecting the costs of ports and coastal activities (Santos Júnior et al., 2023). The study is limited to quantitative data on cost management within the Navy and does not include other Armed Forces or federal government entities.

This study is structured into five sections. The first section addresses the topic by presenting the context, justification, and relevance, as well as the scope of the research. The second section presents a literature review on cost management within the Navy, administrative expenditures and workforce, the costs of ports and coastal services, and the study variables, in order to provide a theoretical framework. The third section outlines the methodology employed, while the fourth section presents the research findings. Finally, the last section discusses the concluding remarks and recommendations for future research.

2. THEORETICAL FRAMEWORK

With the aim of examining the subject matter and achieving the proposed objectives, the theoretical framework addresses the main concepts of cost management in the public sector, as well as within the Brazilian Navy. It also presents the study variables and the concept of linear regression, emphasizing its importance in public resource management and in enhancing transparency and control.

2.1 Cost Management in the Brazilian Navy

The literature indicates that, although the public sector faces unique challenges, cost accounting can help align resources with expected outcomes, as suggested by Santos Júnior et al. (2023b).

The Federal Constitution of Brazil establishes the principles that guide Public Administration, among which the principle of efficiency stands out, requiring positive outcomes in the provision of public services (Brazil, 1988). Alonso (2022) states that

"efficiency is the relationship between results and the cost required to achieve them." The author argues that, in order to properly assess public service performance, systems must provide managerial and cost information. Thus, there can be no measurement of efficiency without the measurement of costs. Cost management in the public sector, implemented following Law No. 4,320 of March 17, 1964, has been widely discussed due to the need to maximize resource efficiency and ensure transparency. According to Alonso (2022) and Freitas et al. (2021), the adoption of cost systems in public organizations enhances accountability and enables a more effective allocation of budgetary resources.

From this perspective, according to the Federal Accounting Council (CFC, 2021), the Cost System in the public sector aims, among other objectives, to develop cost management models based on established guidelines, with the purpose of generating cost information focused on planning processes, decision-making, monitoring, performance evaluation, transparency, reporting, and accountability.

Studies such as those by Alonso (2022); Mello et al. (2021), Mello et al. (2024); Silva et al. (2025); and Santos Júnior et al. (2023a) highlight the role of cost accounting in enhancing the operational efficiency of public organizations. Additionally, international studies such as Inglot (2024), which explores the application of cost-effectiveness models in the public sector, and Pehlivan and Cicek (2023), which examine the use of Activity-Based Costing (ABC) supported by simulation, underscore the relevance of resource consumption linked to activities.

In the military context, Cost Systems are essential, as they ensure operational sustainability, as noted by Mello et al. (2021), Santos Júnior et al. (2023), Mello et al. (2024), and Silva et al. (2025). The adoption of quantitative tools, such as cost analysis and predictive models, is important for optimizing resource management in military organizations, as well as supporting decision-making processes. The authors argue that effective control of administrative and personnel costs is vital to ensure that critical operations are carried out efficiently, without compromising the mission or available resources.

Cost management in the Brazilian Navy is a strategic issue for ensuring the efficiency of military and administrative operations. The Navy invests in efficient cost management to allocate resources rationally and ensure that its operations—both in security-related areas and in maritime authority activities—are maintained in a manner that ensures economy, effectiveness, and efficiency (Brazil, 2020).

Thus, according to Santos Júnior et al. (2023), the Navy's Cost System enables a detailed view of the costs of activities and, consequently, a thorough assessment of the allocation of available resources. In this regard, with the purpose of determining the costs associated with Waterway Traffic Safety activities, the Navy established macro-activities, including the Ports and Coastal Services (Macro-activity 04.00) and Administrative Activities (Macro-activity 59.00), as defined in Standard SGM-307 (Brazil, 2020a).

According to Alonso (2022), the use of methodologies such as Activity-Based Costing (ABC) is fundamental for identifying operations that consume resources, as well as for allocating indirect costs. In this regard, the Cost System of the Brazilian Navy adopts the ABC method, which assumes that activities consume organizational resources (Silva et al. 2025).

Santos Júnior et al. (2023). The purpose of this method is to identify the activities required for service delivery based on resource utilization and, accordingly, allocate costs (Pehlivan & Çiçek, 2023). This method provides a more detailed view of the costs associated with each operation, highlighting key cost centers and facilitating the identification of areas that require tighter financial control (Garrison et al., 2013).

Furthermore, the Brazilian Navy has implemented cost planning and control tools that integrate performance analysis with the institution's strategic objectives, as highlighted by Santos Júnior et al. (2023b). This approach enables improved cost forecasting and more efficient resource allocation, particularly in more complex activities such as maritime inspection, fleet maintenance, and logistics operations in territorial waters.

Thus, the use of information systems such as the Navy Cost System (SCM), the Integrated Financial Administration System of the Federal Government (SIAFI), the Federal Government Cost Information System (SIC), and Treasury Management enables the Brazilian Navy to record, calculate, organize, and monitor the costs incurred across its various activities, with the aim of generating managerial information to support decision-making processes, as well as enhancing transparency and accountability in the use of public resources (Brazil, 2020).

2.2 Administrative Expenditures, Workforce, and the Costs of Ports and Coastal Services

Administrative costs are a central component in determining the operational costs of Military Organizations (MOs), especially in high-complexity contexts where efficiency in controlling administrative expenditures can significantly improve the allocation of resources in operations (Santos Júnior et al., 2023). In addition, the authors highlight that personnel per diem expenses constitute a relevant cost for measuring efficiency in inspection activities.

In Brazil, the Brazilian Navy faces challenges in controlling its administrative and personnel expenditures, as corroborated by Alonso (2022), Mello et al. (2021), and Mello et al. (2024). These authors suggest that, through efficient cost management, MOs can improve cost predictability and planning, as well as optimize resource allocation, thereby promoting greater operational efficiency.

According to Freitas et al. (2021), the strategic allocation of the workforce can not only increase productivity but also significantly reduce operational costs by identifying areas with excess personnel or inadequate allocation of human resources. According to these authors, workforce management is one of the major challenges for public organizations, including the Military Organizations (MOs) of the Brazilian Navy, as it involves not only managing large personnel contingents but also optimizing their allocation according to operational needs, with the aim of maximizing efficiency and minimizing associated costs.

Costs associated with Maritime Authority operations include infrastructure maintenance, vessel maintenance, technology, and personnel expenditures, all of which are essential for carrying out activities such as inspection and maritime safety (Santos Júnior et al., 2023).

According to Santos Júnior et al. (2023), cost analysis in the context of waterway traffic safety activities demonstrates how the allocation of investments and the appropriation of costs in the most efficient manner can lead to “the maximization of the execution of inspections and naval surveys in each District Area.”

This study suggests that high costs in Maritime Authority activities may compromise the sustainability of operations. In turn, Alonso (2022) emphasizes the need for cost-containment measures and cost reassessment strategies, especially in periods of budgetary constraints.

3. METHODOLOGY

The methodology of this study was designed based on the principles proposed by Gil (2008) and Vergara (2007), providing a scientific framework. The research follows a quantitative approach, guided by criteria for data collection, analysis, and interpretation, in order to ensure the internal and external validity of the results. The main elements of the adopted methodology are described below.

3.1 Research Method

According to Vergara (2007), with regard to its purpose, this study is both descriptive and explanatory, as it describes and analyzes administrative costs and workforce allocation in the Military Organizations (MOs) of the Brazilian Navy and explains how these variables influence the costs of ports and coastal activities.

This research is descriptive in nature as it outlines the characteristics of the MOs within the CDA network and establishes and analyzes correlations among the variables. In addition, it constitutes an explanatory investigation, which is appropriate when the objective is to clarify characteristics and predict certain phenomena based on numerical data. This aligns with the objectives of the present study, as its purpose is to build an explanatory model capable of identifying how the variables ADM (administrative expenditures) and WF (workforce) directly influence the costs of port and coastal activities (Vergara, 2007).

According to Gil (2008), this study adopts a quantitative approach. This approach was selected for its ability to generate numerical data that can be subjected to statistical analysis, thereby enabling the identification of patterns and relationships among the variables of interest.

To this end, secondary Brazilian Navy, as well as from financial and administrative reports of the MOs.

Given that cost management is a field widely examined based on objective data, the analysis of correlations and regressions allows for assessing how different variables impact operational costs, thereby enabling the development of predictive models and the testing of hypotheses.

3.2 Data Collection and Processing

Data collection was conducted using secondary sources. Existing data were used for this research, as they are appropriate for quantitative analysis (Lakatos & Marconi, 2017). The primary sources included the Sistema Integrado de Administração Financeira do Governo Federal (SIAFI) and the Information System

the Federal Government Cost Information System (SIC), and Treasury Management, in addition to management reports from the Military Organizations (MOs) within the CDA network.

The Integrated Financial Administration System of the Federal Government (SIAFI) and Treasury Management are platforms used by the Federal Government to manage financial and accounting information of federal public entities, providing data on revenues, expenditures, and costs. These systems enabled the collection of data on administrative expenditures and workforce-related expenses.

According to Vergara (2007), institutional reports provide a comprehensive and standardized view of the activities performed. Management Reports—annual accountability documents—present consolidated data published yearly by the Military Organizations (MOs), thereby facilitating comparative and longitudinal analysis. From these reports, data were extracted on the distribution of financial and human resources, as well as on operational and maintenance costs of the MOs involved in Waterway Traffic Safety activities.

The collected data refer to ADM (administrative expenditures), WF (workforce), and PCS (ports and coastal services costs), covering the period from 2020 to 2023. ADM comprises expenditures related to the general functioning of the Military Organizations (MOs); such expenditures are essential to ensure that the operations of the Brazilian Navy, particularly regarding its role as Maritime Authority, are carried out continuously and efficiently (Alonso, 2022). WF represents the human resources allocated across the various functions within the MOs, including both operational military personnel directly or indirectly involved in ports and coastal activities (Freitas et al., 2021). PCS refers specifically to expenditures associated with waterway traffic control operations, port maintenance, maritime safety, and other activities related to the regulation and operation of Brazil's navigable waterways (Santos Júnior et al., 2023).

At the end of the data collection period, three main variables were defined: PCS as the dependent variable, and ADM and WF as independent variables. These variables were selected based on the existing literature, which highlights the relevance of administrative expenditures and workforce in determining operational costs (Freitas et al., 2021; Inglot, 2024). The main hypothesis is that both ADM and WF are directly related to PCS, with positive and statistically significant effects.

Based on these data and the defined variables, model estimation was conducted. To this end, Multiple Linear Regression was employed, enabling—based on the results of the predictive model—the provision of an effective tool for managers to support budget planning and optimize resource allocation according to the operational needs of the MOs (Gujarati & Porter, 2021).

This methodology is widely used in cost studies to model the relationship between explanatory and dependent variables (Gujarati & Porter, 2021). According to Stevenson (2021), this technique allows for predicting the impact of variables such as administrative costs and workforce on total operational costs. Stevenson (2021) and Gujarati and Porter (2021) agree that multiple linear regression is an effective tool for identifying the variables that most influence operational costs, thereby enabling managers to make proactive adjustments.

Thus, it was possible to establish the model equation using the R software, based on the Ordinary Least Squares (OLS) method, a standard procedure for model estimation.

multiple linear regression models were estimated using the Ordinary Least Squares (OLS) method, which minimizes the sum of squared residuals, ensuring that the regression line provides the best fit to the observed data.

The R software, used to perform the statistical analyses, offers a wide range of packages for multiple linear regression modeling and diagnostic analysis (R Core Team, 2019). Functions such as *lm()* were used to estimate the model, and *bptest()* was employed to test for homoscedasticity, among others. The use of R enabled the generation of graphical outputs and detailed reports that support the visual interpretation of results, as well as ensuring the reproducibility of the procedures. To assess model adequacy, F-tests and t-tests were conducted to evaluate the overall significance of the model and the individual significance of each regression coefficient, respectively (Stevenson, 2001).

The F-test was used to test the null hypothesis that all regression coefficients are equal to zero ($H_0: \beta_1 = \beta_2 = 0$), which would imply that the independent variables have no effect on the costs of ports and coastal services. A p-value below 0.05 indicates rejection of the null hypothesis, meaning that the model as a whole is statistically significant.

The t-test was used to assess the individual significance of each regression coefficient. For each independent variable, the null hypothesis was that the corresponding coefficient equals zero ($H_0: \beta_1 = 0$ or $\beta_2 = 0$). Again, a p-value below 0.05 indicates that the coefficient is significantly different from zero, implying that the independent variable makes a statistically significant contribution to explaining cost variability.

In addition, further diagnostics were conducted to verify the validity of the assumptions underlying the linear regression model, including multicollinearity analysis (using the Variance Inflation Factor—VIF), residual normality testing (Kolmogorov–Smirnov test), and homoscedasticity testing (Breusch–Pagan test). These procedures ensure that the model meets the assumptions required for valid statistical inference.

The robustness of the results was ensured through the estimation of confidence intervals for the model parameters and the application of diagnostic tests. Ninety-five percent confidence intervals were computed for the regression coefficients, providing a measure of estimation precision. Furthermore, the adjusted R^2 was used to evaluate the explanatory power of the model, ensuring that the variability

of costs was adequately explained by the selected independent variables (Stevenson, 2001).

Thus, the multiple linear regression model equation used in the study can be expressed as follows:

:

$$SPC = \beta_0 + \beta_1 ADM + \beta_2 FT + \varepsilon \quad (1)$$

Where:

- PCS is the dependent variable, representing the costs of ports and coastal services;
- ADM and WF are the independent variables, representing administrative expenditures and workforce, respectively.
- β_0 is the intercept of the model;
- β_1 and β_2 are the estimated regression coefficients for the ADM and WF variables; and
- ε represents the residual error term, which captures the variation not explained by the model's variables.

4. ANALYSIS AND DISCUSSION OF RESULTS

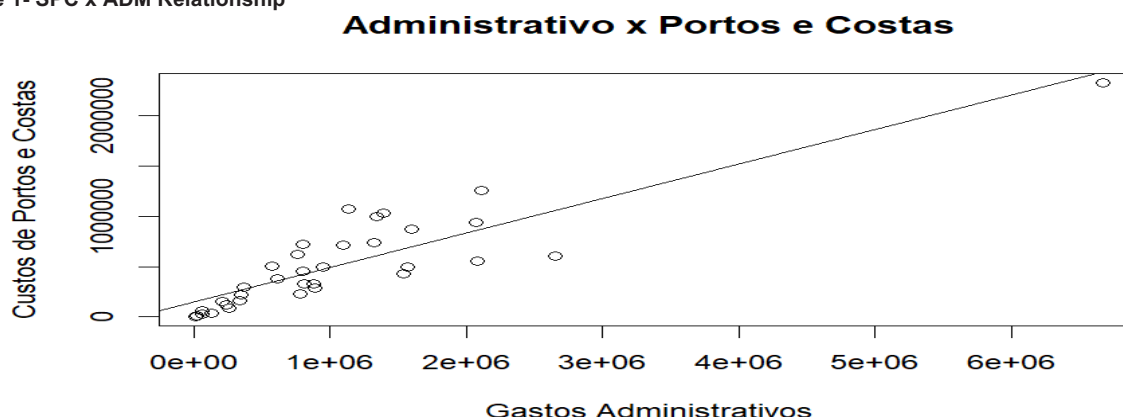
This section presents the analysis of the results obtained in this study, based on a multiple linear regression model, which highlights the relationship between the costs associated with ports and coastal activities carried out by the Military Organizations (MOs) within the CDA network and their administrative expenditures and workforce allocation.

4.1 Exploratory Data Analysis

In an exploratory data analysis, the variables listed for adjusting the multiple linear regression model were observed, namely: Port and Coastal Service Costs (SPC); Administrative Costs (ADM) and Workforce (FT). The SPC variable was established as the dependent variable, while the ADM and FT variables were independent.

In this way, it was observed that the dependent variable SPC has positive correlations of 0.88 and 0.81 with the independent variables ADM and FT, respectively, demonstrating that the costs associated with port and coastal services of the CDA network's military units are strongly correlated with the expenses related to the administrative structure of the military units, as well as the number of military personnel employed to perform their activities.

Figure 1- SPC x ADM Relationship

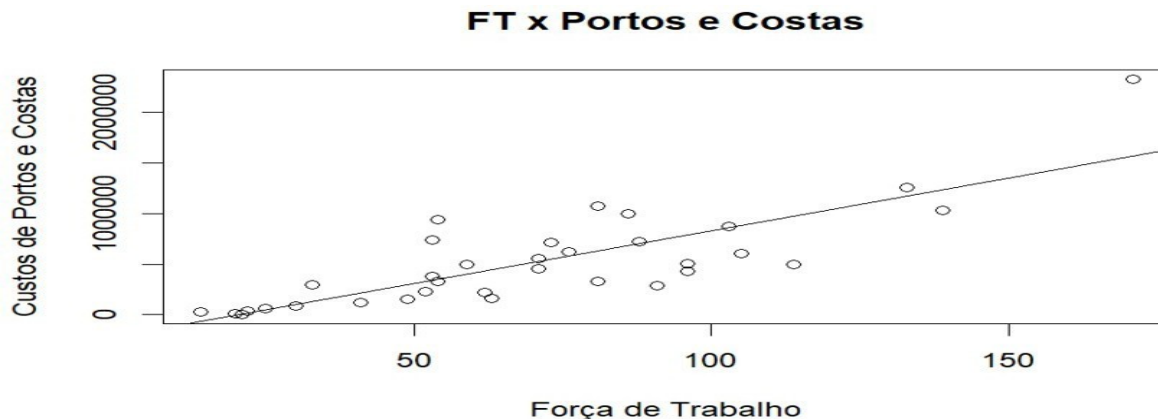


Source: Survey data (2024).

Figure 1 illustrates the direct relationship between the variables SPC and ADM, indicating that the greater the volume of ADM, the

greater the volume of SPC. Each point highlighted in the graph indicates an OM that develops activities related to the safety of waterway traffic.

Figure 2 – Relation SPC x FT



Source: Survey data (2024).

In parallel, Figure 2 shows the relationship between the variables SPC and FT, which also indicates a direct relationship, showing that the greater the number of personnel employed to perform the tasks of the Military Organizations of the CDA network, the greater the cost recorded in the Macro-activity of "04.00 – Port and Coast Services". This fact demonstrates that the allocation of the contingent of military personnel to operate vessels and equipment intended for the fulfillment of this type of activity generates a greater increase in the costs of this activity.

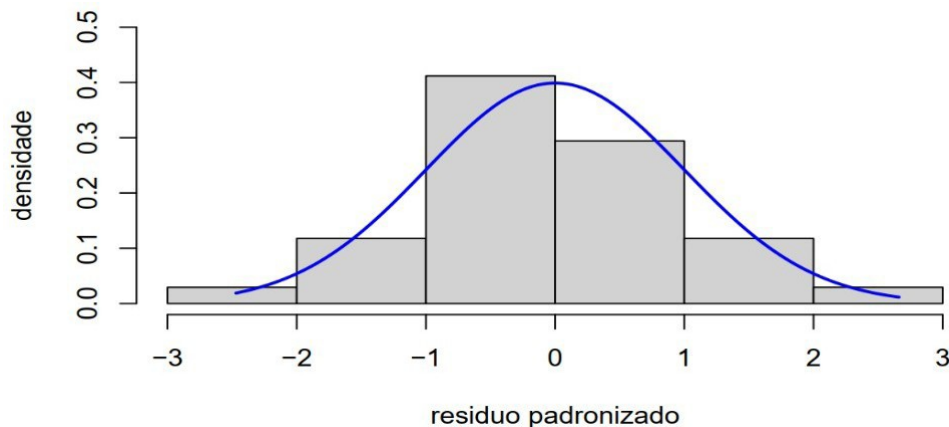
In this sense, after carrying out this preliminary analysis, it was possible to observe that the variables ADM and FT presented characteristics that make them good candidates for the composition of the multiple linear regression model that explains the costs of port and coast services of the Military Organizations of the Captaincies, Delegations and Agencies (CDA) network of the Brazilian Navy. The model is represented by equation 1, where the intercept β_0 and

the regression coefficients β_1 and β_2 are parameters to be estimated by least squares (Gujarati, 2000), while ε denotes independent and normally distributed random errors with a mean equal to zero and variance $\sigma\varepsilon^2$.

4.2 Testing the Assumptions

As part of the validation process of the multiple linear regression model obtained for estimating the cost of ports and coasts in the CDA network's OM, a diagnosis of the residuals was performed, so that it is possible to analyze the assumptions made by the least squares model for the error component. Among the hypotheses established for the errors of a linear regression model is that they have a normal distribution and are homoscedastic ($\sigma\varepsilon^2$ constant).

Figure 3 - Waste Distribution



Source: Survey data (2024).

Thus, as shown in Figure 3, the distribution of the residuals was obtained, making it possible to preliminarily analyze said distribution, as well as verify if there is an approximation with the normal distribution.

Figure 3 reveals the adherence of the empirical distribution

of the residuals to the normal distribution., a result confirmed by the Kolmogorov-Smirnov test, whose hypotheses are presented below:

H0: the residues have a normal distribution

H1: waste is not being distributed normally.

Figure 4

Residual normality test

```
> #Teste de Normalidade de Kolmogorov-Smirnov (normalidade dos resíduos)
> ks.test(sresid,"pnorm")
```

Exact one-sample Kolmogorov-Smirnov test

```
data: sresid
D = 0.10521, p-value = 0.8084
alternative hypothesis: two-sided
```

Source: Research data (2024).

The Kolmogorov-Smirnov test was operationalized using the R software, the result of which is shown in Figure 4.

The p-value of the test was approximately 0.8084, therefore, the null hypothesis that the residuals have a normal distribution was not rejected at the 5% significance level. This result aligns with the analysis performed based on Figure 4.

To verify the assumption of homoscedasticity of errors, the Breusch-Pagan test was performed, whose hypotheses are presented below:

H0: Homoscedasticity (No heteroscedasticity)

H1: Heteroscedasticity exists

For this purpose, the lmtest package of the R software was used, in which the bptest command enabled the Breusch-Pagan test to be performed, the result of which can be seen in Figure 5.

Figure 5 - Breusch-Pagan Test

```
> library(lmtest)
> bptest(modelo)
```

studentized Breusch-Pagan test

```
data: modelo
BP = 3.7172, df = 2, p-value = 0.1559
```

```
> |
```

Source: Survey data (2024).

As observed, the p-value of the Breusch-Pagan test was 0.1559, indicating that the assumption of homoscedasticity of errors was not rejected at the 5% significance level. Therefore, the above considerations allow us to conclude that the multiple linear regression model is adequate.

4.3 Linear Regression Model Adjustment

Using the linear models (lm) function in the R software, it was possible to obtain the statistical results shown in Figure 6, which enabled the execution of the inherent hypothesis tests.

to the checks that make up the process of adjusting the multiple linear regression model.

Based on the statistical results, the F and t statistical tests were performed, in addition to the analysis of the R2 of the model obtained. First, the F test was performed, whose hypotheses are defined as follows:

H0: $\beta_1 = \beta_2 = 0$ all regression coefficients are equal to zero

H1: $\beta_1 \neq 0$ or $\beta_2 \neq 0$ at least one of the regression coefficients is different from zero. Next, the t-test was performed to assess the statistical significance of each regression coefficient.

HH0: Regression coefficient equals zero

H1: Regression coefficient is different from zero

According to the results shown in Figure 6, the F(71.11) statistic is significant (p-value $< 2.617 \times 10^{-12}$); therefore, the null hypothesis that all regression coefficients are simultaneously zero is rejected. Thus, the regression equation has overall significance, that is, the proposed regression equation provides a better fit than the average of the costs.

Additionally, also based on the results in Figure 6, it was observed that the regression coefficients are positive, aligning with the information obtained in the exploratory data analysis, and statistically significant at the usual significance levels (p-values $< 8.74 \times 10^{-6}$ and < 0.00668). Thus, both regression coefficients are positive and statistically different from zero. The R2 statistic points to an adjusted model that explains 82.10% of the total variability in the costs of port and coastal services of the CDA network, therefore, the model presents a good fit.

Figure 6 - Model Tuning Results

```
> # obtendo o modelo
> modelo=lm(SPC~ADM+FT,data=dados)
> summary(modelo)

Call:
lm(formula = SPC ~ ADM + FT, data = dados)

Residuals:
    Min       1Q   Median       3Q      Max
-449134  -79661  -12542   134064   489611

Coefficients:
            Estimate Std. Error t value Pr(>|t|)
(Intercept) -4.816e+04  8.267e+04  -0.583  0.56439
ADM          2.424e-01  4.561e-02   5.314  8.74e-06 ***
FT           4.359e+03  1.499e+03   2.907  0.00668 **
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 204800 on 31 degrees of freedom
Multiple R-squared:  0.821,    Adjusted R-squared:  0.8095
F-statistic: 71.11 on 2 and 31 DF,  p-value: 2.617e-12
```

Source: Research data (2024).

Figure 7 - Confidence Intervals

```
> confint(modelo)

                2.5 %                97.5 %
(Intercept) -2.167792e+05 1.204513e+05
ADM          1.493364e-01 3.353925e-01
FT           1.300754e+03 7.416783e+03
> |
```

Source: Research data (2024).

Using the *confint* (model) function, executed in the R software, the limits of the 95% confidence intervals of the regression equation parameters (β_0 , β_1 and β_2) were obtained, as shown in Figure 7.

In this context, according to the verifications carried out by the F and t tests, of the confidence intervals of the regression coefficients, and the analysis of the R² of the model, it was possible to obtain the multiple linear regression equation, represented by Equation 2.

$$\text{Cost SPC} = 0.24\text{ADM} + 4.359\text{FT} - 48.160 + \epsilon \quad (2)$$

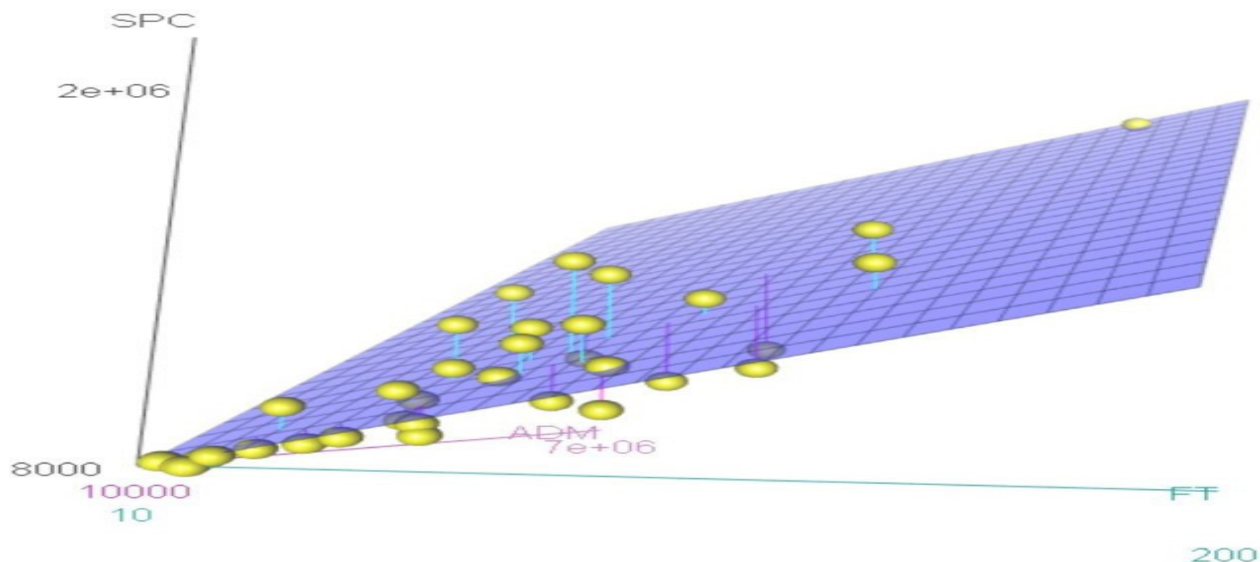
The aforementioned equation expresses the relationship between the costs of Macro-activity "04.00 – Port and Coastal Services" (SPC) and the costs recorded in Macro-activity "59.00 – Administrative Activities" (ADM) and the total workforce (FT) of each Military Organization (OM). Thus, the variation in cost associated with the SPC variable is described by the two explanatory variables (ADM and FT), such that each R\$ 1.00 allocated to the costs of administrative activities corresponds to R\$ 0.24 in costs of activities related to port and coastal services, and each military member allocated to the workforce of these OMs contributes an increase of R\$ 4,359.00 to the cost of SPC. Based on this result, it is possible to infer that the obtained model can be used in the planning process of

Captaincies, Delegations and Agencies, regarding the need for resources to support activities related to port and coastal services (Macro-activity 04.00) for a given fiscal year, using as parameters the estimate of administrative expenses (Macro-activity 59.00) and the availability of personnel to carry out these activities. Therefore, the allocation of resources to the administrative structure of this type of OM and the availability of personnel for a given fiscal year will provide an estimate of the costs of their core activities and may guide the need for resources to be allocated to cover these costs.

Additionally, in a scenario of budgetary constraints, the projection of the costs of Macro-activity 04.00 may indicate whether the resources available for these activities can support the estimated demand, which may result in a reduction in the level of service.

Subsequently, with the aid of the R software, it was possible to generate the visualization of the regression plane (Figure 8). In this case, the equation of the fitted model is represented by the plane that passes through the point cloud, where each point corresponds to an OM of the CDA network considered in the sample. The aforementioned plane has a slope in the direction of administrative costs (ADM) and labor force (FT). As the values of these variables increase, the values of port and coastal service costs (Macro-activity 04.00) also increase.

Figure 8 - Regression Plan



Source: Survey data (2024).

It should be noted that the aforementioned plan does not provide the exact cost of Macro-activity 04.00, but rather the expected cost level of the port and coastal service, which, in relation to the level of administrative expenses and the employment of military personnel in the tasks of each Military Organization in a given fiscal year, presents itself as a predictive

cost model, and can be a tool to assist managers in budgetary planning and in the managerial accounting activities of the Captaincies, Delegations and Agencies.

5. FINAL CONSIDERATIONS

Starting from the main objective of analyzing how ADM and FT influence operational costs, it was possible, through a quantitative approach and the application of a multiple linear regression model, to verify that both variables have a direct and significant impact on the costs of the Maritime Authority's core activities. This finding is in line with the specialized literature, which points to the need for rigorous measurement and control of costs in the public sector as a way to ensure efficiency and transparency (Alonso, 2022; Santos Júnior et al., 2023a).

Regarding the first specific objective, namely, to evaluate the correlation between ADM and SPC, the study showed a strong positive correlation (0.88), suggesting that the higher the administrative expenses, the greater the impact on operating costs, keeping all other variables constant. This result confirms Alonso's (2022) findings that the efficiency of public management depends on the rationalization of administrative expenses. Furthermore, it reinforces the guideline of NBC TSP 34 (CFC, 2021), which highlights the importance of cost control as a governance and accountability mechanism in the public sector.

Regarding the second specific objective, which sought to verify the impact of the workforce on the SPC, a significant correlation of 0.81 was identified. This finding converges with the studies of Freitas et al. (2021), which highlight workforce management as one of the main challenges for public organizations. The study also indicates that the number of military personnel allocated to port and coastal activities directly influences the operational costs of these activities, corroborating the importance of efficient workforce management for cost containment. The data show that a larger number of personnel generates an increase in operational costs, highlighting the need for strategies to optimize the allocation of human resources.

The third specific objective, aimed at developing a predictive model, was also achieved. The adjusted multiple linear regression model showed good explanatory power, with an adjusted R^2 of 82.10%. This methodological approach finds support in Gujarati and Porter (2021) and Stevenson (2001), who point to multiple linear regression as a robust tool for cost analysis in the public sector. The generated model allows for the estimation of

operational costs based on changes in administrative expenses and workforce, offering a tool to support decision-making by managers of the CDA network's operational units.

The research, by achieving its three specific objectives, reinforces the fulfillment of the main objective of analyzing the influence of ADM and FT on SPC. The study demonstrated that inadequate management of ADM and poor allocation of FT can lead to a considerable increase in operational costs. On the other hand, the application of predictive models based on reliable data contributes to the optimization of resource allocation and the improvement of institutional performance, as already suggested by Santos Júnior et al. (2024) and Mello et al. (2024), especially in contexts of fiscal constraint.

The findings of this study also corroborate the principles of Stakeholder Theory (Góes et al., 2021), demonstrating how transparency and effectiveness in the application of public resources are essential to meet the expectations of society. The practical contribution of this research lies in the possibility of using the developed model as a tool for budgetary planning and strategic personnel management within the Brazilian Navy.

As limitations of the study, the period from 2020 to 2023 for data analysis may limit the generalization of the findings to other periods or economic contexts. In addition, the research was restricted to the Military Organizations (OM) of the network of Captaincies, Delegations and Agencies (CDA) of the Brazilian Navy, not including other military units or public bodies that perform similar activities.

Finally, this research offers a theoretical and practical contribution to the field of controllership and public management by highlighting the importance of using quantitative tools to improve operational efficiency, thus allowing for more precise resource allocation, efficient budget planning, and assertive decision-making, especially in contexts of fiscal constraint. It is recommended that future research explore the impact of other variables, such as the use of technology, the quality of maintenance processes, and the nature of logistical operations, as well as the application of techniques such as data envelopment analysis (DEA), as already proposed by Pehlivan and Çiçek (2023) and Santos Júnior et al. (2023b), in order to deepen the understanding of efficiency in the public sector, especially in military organizations.

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