Journal of Infrastructure, Policy and Development 2025, 9(1), 10927.
https://doi.org/10.24294/jipd10927

Article

Evaluation of management and efficiency in highly complex public hospitals in Colombia: A statistical and financial analysis of KPIs

Robinson Dueñas Casallas[1,*], Cristina Crespo Soler[2], V. Mateo Ripoll Feliu[2], Carlos A. Álvarez Moreno[3]

[1] Faculty of Economic Sciences, New Granada Military University, 110111 Bogotá, Colombia
[2] Accounting Department, Faculty of Economics University of Valencia, 46010 Valencia, Spain
[3] Faculty of Medicine, National University of Colombia, 111321 Bogotá, Colombia
*** Corresponding author:** Robinson Duenas Casallas, robinson.duenas@unimilitar.edu.co

CITATION

Dueñas Casallas R, Crespo Soler C, Ripoll Feliu VM, Álvarez Moreno CA. (2025). Evaluation of management and efficiency in highly complex public hospitals in Colombia: A statistical and financial analysis of KPIs. Journal of Infrastructure, Policy and Development. 9(1): 10927. https://doi.org/10.24294/jipd10927

ARTICLE INFO

Received: 16 December 2024
Accepted: 13 January 2025
Available online: 21 January 2025

Abstract: Management and efficiency have a fundamental impact on the performance of public hospitals, as well as on their philanthropic mission. Various studies have shown that the financial weaknesses of these entities affect the planning, setting of goals and objectives, monitoring, evaluation and feedback necessary to improve health systems and guarantee accessibility as an inalienable right. This study aims to analyze the management and efficiency of third-level and/or high-complexity hospitals in Colombia, through a statistical model that uses financial analysis and key performance indicators (KPIs) such as ROA, ROE and EBITDA. A non-experimental cross-sectional design is used, with an analytical-synthetic, documentary, exploratory and descriptive approach. The results show financial deficiencies in the hospitals evaluated; hence it is recommended to make adjustments in the operating cycle to increase efficiency rates. In addition, the use of the KPIs ROA and ROE under adjusted models is suggested for a more precise analysis of the financial ratios, since these adequately explain the variability of each indicator and are appropriate to evaluate hospital management and efficiency, but not in EBITDA ratio, hence the latter is not recommended to evaluate hospital efficiency reliably. This study provides relevant information for public health policy makers, hospital managers and researchers, in order to promote the efficiency and improvement of health services.

Keywords: management; efficiency; economic resources; public hospitals; financial indicators

1. Introduction

Evaluating hospital management and efficiency is a crucial matter that impacts both the financial sustainability of these entities and public health worldwide. Faced with the growing demand for healthcare, cost variability and budgetary constraints, health systems face multiple challenges. In this context, having objective and accurate information on their financial situation is essential to overcome these difficulties. This has been widely studied by different authors who have addressed various operational, accounting, management, budget, efficiency and hospital economic perspective aspects, highlighting the importance of management and organizational efficiency (Ekiz Bozdemir et al., 2021; Eldenburg and Krishnan, 2006; Fiondella et al., 2016; Hammad et al., 2010; Llewellyn et al., 2005; Moons et al., 2019; Ramanathan, 2005; Van Erp et al., 2019).

Based on the above, hospitals face challenges arising from poor accounting and financial processes, as well as a lack of management control and efficiency, which makes decision-making difficult, among other aspects. This article is derived from a previous bibliometric and systemic study, carried out under the Proknow-C

methodology, which identified new research gaps in management control and accounting in the health sector. In particular, gaps are pointed out in the application of KPIs to analyze the management and efficiency of hospitals, in order to promote a positive impact on their strategic direction (Banditori et al., 2013; Meredith et al., 2011).

The objective of this study is to evaluate the management and efficiency of tertiary level and/or high complexity hospitals in Colombia, through a statistical model that uses financial analysis and key performance indicators (KPIs) such as ROA, ROE and EBITDA (Macinati and Rizzo, 2016; Van Erp et al., 2019), proposing financial improvement plans that tend towards the efficiency of public resources, improvement of the health service, update public health policies and promotion of the achievement of the Sustainable Development Goals SDGs, specifically the third Health and Well-being of the United Nations 2030 Agenda.

The models used were pooled OLS (M1), Fixed Effects (M2) and random effects (M3). The results of the statistical models on ROA ratio showed that, for better performance, hospitals must reduce the operating cycle, which streamlines inventory management and collections, controls debt, and improves working capital and efficiency. In turn, the statistical models on ROE ratio revealed that higher debt over assets has a positive impact when management control is adequate and favorable for return. In terms of validity of the models, it was found that the adjusted ones adequately explain the variability in ROA and ROE, but not in EBITDA ratio, hence the latter is not recommended to evaluate hospital efficiency reliably.

2. Literary review

The lack of timely, accurate and updated financial information generates inequalities in the use of public hospital resources, affecting the provision of health services, with a direct negative impact on operating costs and the efficiency of health systems. According to Eldenburg and Krishnan (2006) and Hammad et al. (2010), the accounting system in hospitals requires administrative monitoring of patients through billing, clinical cost supports and operations of each health entity. However, in developing countries, public hospitals have poor Chief Executive Officer (CEO) direction and ineffective management control, generating high resource consumption. That is why, in for-profit hospitals, expenses and costs are higher than in non-profit hospitals, which influences efficiency, operating margins and financial performance.

Italy and the United Kingdom have worked with programs focused on improving hospital costs and budgets by introducing management accounting. Bosa (2010), through a qualitative empirical case study between 1999 and 2004, analyzed the introduction of new accounting systems, seeking to improve management and financial performance in the health sector, based on an approach that allows to understand budgetary and administrative changes, evidencing a lack of knowledge of accounting processes and hospital costs, committing management and health personnel to training in efficiency to improve patient care. This research adds value and proves that it is possible to apply management accounting through the timely use of financial information, control, efficiency and ethics of the health system.

Llewellyn et al. (2005) conducted an empirical study comparing costs, incentives

and changes in the allocation of hospital resources in the United Kingdom (250 hospitals) and Canada (100 hospitals), confirming that in Canada they are higher and that the system of incremental payment to doctors was directly related to variations in the cost of their extra-work community work. Contrary to the above, in the United Kingdom the costs are lower, since they do not operate at full capacity due to the lack of health personnel, which they try to mitigate with reward strategies for those who provide their services in different entities.

Fiondella et al. (2016) and Ghandour et al. (2022) demonstrated that one way to optimize costs and efficiency in hospitals lies in the quality of service. This requires technological investment, which returns in a marginal benefit as a result of the care that patients receive. In Italy, healthcare organizations are implementing Management Accounting System (MAS) that measures performance and medical care, promoting surpluses and efficiency in healthcare systems. From this perspective, implementing an adequate management control system optimizes processes and cost analysis, budget and performance indicators, creating an organizational culture of efficiency and budgetary quality.

Spain has shown changes in the financial structure of the healthcare sector, due to a decrease in public spending and an increase in healthcare demand. A study to determine the variables influencing the financial structure of Spanish hospital entities during the period between 2008 and 2015, demonstrated the relevance of a long-term financial vision and the analysis of their financial statements, and different ratios characterized and analyzed the results, showing that the hospitals in this study have an adequate distribution of their financial assets and liabilities and an acceptable quality of debt. They must improve the management of their assets and verify that the level of indebtedness does not harm them, allowing them to know the financial trends and possible modifications for the distribution of resources in the healthcare sector (Creixans and Arimany, 2018).

In the Czech Republic, Popesko et al. (2015) recommend implementing an activity—based costing system that facilitates financial analysis. They studied the profit of hospitals with patients categorized into Diagnosis Related Groups (DRG) through case studies, calculating costs per individual and determining the profit for the hospital stay, and thus confirming that with accurate financial information it is possible to understand the patient-financial relationship and internal processes at the accounting level. Purbey et al. (2007) evaluated the performance of healthcare organizations based on care processes, the measurement of financial and non-financial indicators and other special evaluation criteria, highlighting that the measurement parameters used were classified according to their effectiveness and efficiency. With this study, it is understood that these procedures allow for a comparative analysis of hospital management regarding funds, resources, care, intervention, effectiveness and efficiency, providing detailed information that supports financial and administrative decision making in hospitals.

In our case, in Colombia, owing to the increase in costs, the demand for health services, a possible reform of the health system and the management problems faced by some hospitals in Colombia, especially public ones, it is necessary to monitor financial processes, as expressed in the main objective of this study.

3. Methodology

3.1. Model specification

For this study, we used a non-experimental, cross-sectional design with an analytical-synthetic approach, supported by documentary, exploratory, and descriptive methods, following the methodology used in previous studies (Guimarães and Nossa, 2010; Kraus et al., 2017; Nyland et al., 2017). It was observed that Colombia has 931 public hospitals of the three levels of care or complexity, for this study a controlled, specific and representative selection was made from the beginning of the 27 high complexity hospitals (third level), two were excluded due to lack of information. Other selective factors of the hospitals were characteristics such as services or medical specialties they offer, infrastructure, scientific research and budget allocation, being tertiary level hospitals the ones with the greatest significance in these aspects, a greater social impact and management in terms of health, morbidity and mortality. The data consisted of the financial statements (balance sheet and income statement) for the period 2017–2022, it was taken into account that in Colombia the mandatory use of the International Public Sector Accounting Standards (IPSAS), specifically for the health sector, began in 2017, regulations that apply to the hospitals studied, allowing the analyses and results to be under the international accounting framework. The information was organized in panel data and to assess its distribution, Kolmogorov-Smirnov and Shapiro-Wilk normality tests were performed, taking as a reference the work of Amaral (2024) and Bonhomme and Davezies (2019).

The results indicated that several financial indicators did not follow a normal distribution, hence it was necessary to adjust the statistical models to handle the heterogeneity and non-normal distribution of the data, thus reducing the risk of bias in the conclusions. Twenty-nine financial indicators were developed for each hospital and year, and a statistical analysis was subsequently carried out using the SPSS and R programs, which allowed the information to be processed, in order to evaluate the financial management and efficiency of the sample. From this analysis, three key KPIs were selected: Return on Assets (ROA), Return on Equity (ROE) and Earnings Before Interest, Taxes, Depreciation, and Amortization (EBITDA). Previous studies have used different statistical programs to analyze these same KPIs (Batrancea, 2021; Creixans and Arimany, 2018; Lim and Rokhim, 2021; Siedlecki et al., 2016).

3.2. Collinearity and variable selection

To avoid potential collinearity issues on the independent variables and selection, a correlation analysis was performed using the Pearson coefficient (Jacob and Varadharajan, 2024; Kalnins and Praitis, 2024). The mathematical formula is as follows:

$$r_{ij} = \frac{n\left(\sum X_i X_j\right) - \left(\sum X_i\right)\left(\sum X_j\right)}{\sqrt{\left[n\sum X_i^2 - \left(\sum X_i\right)^2\right]\left[n\sum X_j^2 - \left(\sum X_j\right)^2\right]}} \quad (1)$$

where:

rij It is the relationship between two indicators.

n is the number of observations.

X_i, X_j are the values belonging to both indicators.

Based on the results obtained, it was decided to select 10 variables (ratios or indicators), taking three dependent KPIs as representatives of efficiency: ROA, ROE and EBITDA and seven more indicators that explain their independent behavior: Net working capital, debt ratio (total debt), debt asset, collection rotation period, estimate of difficult debt collection (doubtful accounts), payment rotation period and operating cycle. Subsequently, the variance inflation factor (VIF) is used to discard variables that present collinearity problems (Jacob and Varadharajan, 2024; Salmerón-Gómez et al., 2024). In finding that the Payment rotation period has a high relationship with the other variables, it is decided to discard it, finally leaving 9 variables for the elaboration of the models.

3.3. Models

For the calculation, the *R* software was used in its version 4.3.3, with the readxl, tidyverse, janitor, writexl, car, lmtest and plm libraries, with the latter the models were estimated using the "plm(...)" command.

The final base used for the research consists of 11 variables: nine financial indicators, one variable indicative of each hospital (company name) and one indicating the year of each measurement. Each hospital has six observations of each variable, one per year, giving a total of 66 per hospital and a total of 1650 observations for the entire sample.

In order to determine the optimal use of resources in the sample of hospitals, the KPIs ROA, ROE and EBITDA were taken as a reference for efficiency and the following hypotheses were raised to determine the influence or impact of the other variables (indicators) selected for the study:

Hypothesis 1 (H1) There is a significant relationship between ROA and the selected indicators.

Hypothesis 2 (H2) There is a significant relationship between ROE and the selected indicators.

Hypothesis 3 (H3) There is a significant relationship between EBITDA and the selected indicators.

Using three different models, it is expected to find a relationship between resources and their use over the period of time analyzed, based on the panel, cross-sectional and time series data structure present in the sample. To control non-visible effects, tests were performed to determine their importance for the models and the Hausman test was applied to compare fixed and random effects models. It should be noted that the variables studied were treated under a standardization process due to the difference in their magnitudes and thus improve the interpretability of the results. From this perspective, three models were built:

- Pooled OLS model (M1), which assumes that there are no individual differences between hospitals and the data are treated as if they came from a single sample. In this case, the model ignores any panel structure and treats observations as if they were independent of each other. (Esposito et al, 2024)
- Fixed Effects Model (M2), is used to analyze how independent variables affect the dependent variable, controlled for the specific characteristics of each hospital.

It assumes that there are specific characteristics of each hospital that can influence the dependent variable, which are constant over time, but not observable (Berger and Tutz, 2018; Hill et al., 2020).

- Random Effects Model (M3), assumes that individual differences between hospitals are random and not correlated with the explanatory variables of the model. It is useful when it is hypothesized that individual differences have an impact on ROA, but are not fully captured by the variables included in the model (McKenzie and Veroniki, 2024).

3.4. General model formula for ROA, ROE and EBITDA

$$Y_{it} = \alpha + \beta_1 \text{Net operating working capital}_{it} + \beta_2 \text{Total debt}_{it} + \beta_3 \text{Debt asset}_{it} + \beta_4 \text{Collection rotation period}_{it} + \beta_5 \text{Doubtful accounts}_{it} + \beta_6 \text{Operating cycle}_{it} + u_{it}$$

where:

Y_{it} represents the dependent variable which can be ROA, ROE or EBITDA.

α is the intercept of the model.

$\beta_1, \beta_2, \beta_3, \beta_4, \beta_5, \beta_6$ are the coefficients that capture the impact of each independent variable.

u_{it} is the error term that includes unobserved effects:

In Model 1 (M1: Pooled OLS), u_{it} is the standard error.

In Model 2 (M2: Fixed Effects), u_{it} captures unit-specific unobservable heterogeneity.

In Model 3 (M3: Random Effects), u_{it} includes a random component that captures unobserved variability

3.5. Data sources

Our data was provided by the Ministry of Health and Social Protection of Colombia (MHSPC), under IPSAS in accordance with Law 1314 of 2009, Art.12 Coordination between public entities of the Congress of Colombia and Resolution 663 of 2015 Art.3, period of application of the CGN and others related, applied to the health sector since 2017, granting it a high degree of reliability, accuracy, consistency and comparability of the data.

Data collection process

In the Colombian health system, the MHSPC is the highest regulatory body that regulates and directs everything related to public health, the subject matter and population of this study. In an interview with Dr. Urbano from the Ministry's management of Service Delivery and Primary Care, he guided us on several aspects to analyze the data: hospitals in Colombia are classified according to the level of complexity they serve, their installed physical capacity and the medical specialties available, since 2017, the health sector has applied IPSAS and the hospitals in Bogotá Capital District are grouped into subnetworks, according to their geographic location.

4. Empirical results

These provide a comprehensive description of the statistical significance and validity of the models (M1, M2, and M3). Similarly, **Table 1**, shown below, presents

the statistical tests for contrast and selection, which ensure the reliability and comparability of the findings, enhance the robustness of the analyses, and improve the accuracy of the conclusions.

Table 1. Graphic explanation of the three models for each of the ROA, ROE and EBITDA variables.

	ROA			**ROE**			**EBITDA**		
	M1	M2	M3	M1	M2	M3	M1	M2	M3
Intercept	3.6165E-17	-	4.6687E−17	6.1955E−17	-	1.3225E−17	1.788E-16	-	-1.0161E−17
Net operating working capital	0.046503556*	-0.042851	-0.003346266	0.018908418	-0.055282	0.005067892	-0.519750311***	-0.2783136***	-0.328437102***
Total debt	0.014346533	0.018959	0.015904344	-0.856323233***	-0.867988***	-0.863077745***	-0.163051062*	-0.026569	-0.035035271
Debt asset	-0.108699383***	0.020938	-0.038411815	0.018829866	0.178607***	0.047158947	-0.301581878**	-0.209276*	-0.214079629***
Collection rotation period	0.051747852**	0.035101*	0.035659032*	0.021143204	0.088366***	0.041537528*	0.102797075	0.0086435	0.019014219
Estimate of difficult debt collection doubtful accounts	0.10004-3879***	-0.025162	-0.027917919	-0.089800983***	-0.120103**	-0.090182267**	4603*	-0.1535656	-0.17025196*
Operating cycle	-0.956274502***	-0.977655***	-0.971120297***	-0.481306104***	-0.493316***	-0.485652659***	-0.096137474	-0.0826974*	-0.086033338*
TSS	149	120.66	124.23	149	133.01	139.06	149	17.122	22.812
RSS	8.02	2.4253	3.3731	6.4019	31913	4.8805	106.28	14.666	19.089
R^2	0.94613	0.9799	0.97285	0.95703	0.97601	0.9649	0.28671	0.14346	0.16321
Adjusted R^2	0.94387	0.97483	0.97171	0.95523	0.96996	0.96343	0.25678	-0.072472	0.1281
Statistic *F*	418.582	966.853	-	530.87	806.821	-	9.57979	3.3219	-
Chi Square	-	-	5123.79	-	-	3931.42	-	-	27.8908
P value	0	0	0	0	0	0	0	0.0046411	0.000098516
Test *F*	0.00000000000000022			0.000000001479			0.00000000000000022		
Hausman test result	0.00008447			0.0000004778			0.1621		

Note: The results marked with *, **, *** show statistical significance at the 5%, 1% and 0.1% levels respectively. The F test determines the probability of not including fixed effects, giving greater validity to the M2 and M3 models. The White and Breusch-Pagan tests were performed to reject the existence of heteroscedasticity in the models. Using the variance inflation factor (VIF), the presence of multicollinearity is ruled out by obtaining all values less than 5.

Models applied to the KPI´s ROA, ROE and EBITDA

The analysis of the KPI´s ROA, ROE and EBITDA reveals several common patterns and specific differences in relation to the independent variables evaluated in models M1, M2 and M3. This can be seen in **Table 1** used for the following detailed analysis of results. Esto se puede apreciar en la **Tabla 1** usada para el siguiente análisis detallado de resultados.

The operating cycle emerges as a determining factor with a significant negative impact on ROA, ROE and EBITDA in the three models. In the case of ROA, this indicator shows highly significant coefficients ranging from −0.9563 in model M1 to −0.9777 in model M2, suggesting that a reduction in the operating cycle could increase it. Similarly, the operating cycle has a negative effect on ROE, with coefficients ranging from −0.4813 to −0.4933. For EBITDA, the impact of the operating cycle is less pronounced than for the other indicators, but it is still significant, with values such as −0.0827 in the M2 model.

The collection rotation period also plays an important role, particularly in the models that evaluate ROA and ROE. This indicator has a positive and significant impact on ROA in all models, with coefficients ranging from 0.0517 in M1 to 0.0357 in M3, indicating that an increase in collection efficiency could improve profitability. For ROE, although its significance is lower, it also reflects a positive effect in the three models, reaching 0.0415 in the M3 model.

The total debt ratio is another critical factor, especially in the ROE analysis. This indicator shows a highly significant negative effect in all models, with coefficients ranging from −0.8563 in M1 to −0.8631 in M3, suggesting that a higher debt ratio reduces the return on equity. However, its impact on ROA and EBITDA is less significant, with some models not reaching significance.

For the estimate of difficult debt collection, a positive and significant effect on ROA is observed in models M1 and M3, although its magnitude decreases in model M3 (0.0222). In the case of ROE, this indicator has a negative effect in the three models, with values such as −0.1201 in M2, highlighting the risks associated with the recovery of the portfolio. For EBITDA, this factor is insignificant in most models.

Net operating working capital is particularly relevant in the EBITDA analysis, where it has a consistent and significant negative impact in all models. The coefficients vary from −0.5198 in model M1 to −0.3284 in model M3, indicating that inefficient working capital management could reduce earnings before interest, tax, depreciation and amortisation.

The following three graphs show the results of the three models M1 **(Figure 1)**, M2 **(Figure 2)** and M3 **(Figure 3)** for each of the three KPIs (dependent variables), with respect to the other ratios (independent variables). The following **(Figure 1)** show the result of the M1 OLS Data Pool model

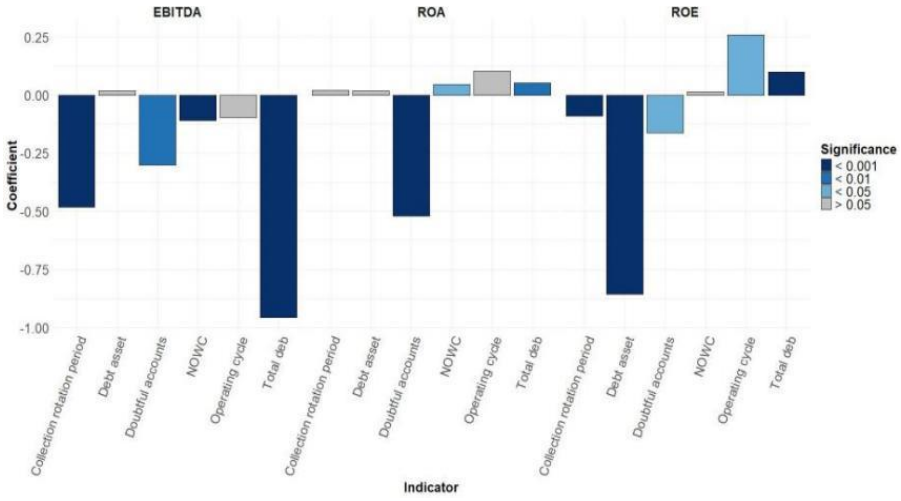

Figure 1. Coefficient by indicator and dependent variable OLS Data Pool model.

In favor of readability, the names of the ratios are reiterated: Net Operating Working Capital (NOWC), Estimate of difficult debt collection (Doubtful accounts).

It should be taken into account that the larger the bar is, the greater the influence on the KPIs, ROA, ROE or EBITDA is, which can be positive (ascending) or negative (descending). In the same way, the colors represent statistical significance, gray when it is not significant at 5% and the darker, the greater the significance. Therefore, if the bar is dark blue and long, it is inferred that this variable is very statistically significant and has a high influence on the KPIs.

In terms of model selection, based on the results of the *F*-test with *p*-values below 0.05 (**Table 1**), it is determined that fixed or random effects models are more appropriate for ROA, ROE and EBITDA. In addition, due to the nature of the data, which comes from a non-random selection, fixed effects models should be chosen to avoid violating the assumption of independence between explanatory variables and unobservable effects. This decision is further supported by the results of Hausman's test (**Table 1**), which indicate that the fixed effects model is the best option, except for specific cases related to EBITDA, identifying the best indicators for estimation, collection rotation period, doubtful accounts and total debt are most relevant for ROA; Debt asset and collection rotation period are key for ROE; and finally, all indicators except net operating working capital and debt asset are significant for EBITDA, as shown in **Figure 2** the following show the result of the Fixed Effects model. It should be clarified that this selection is based on the predictive ability of these models, while maintaining the ability to compare them to determine the impact of the indicators on ROA, ROE and EBITDA.

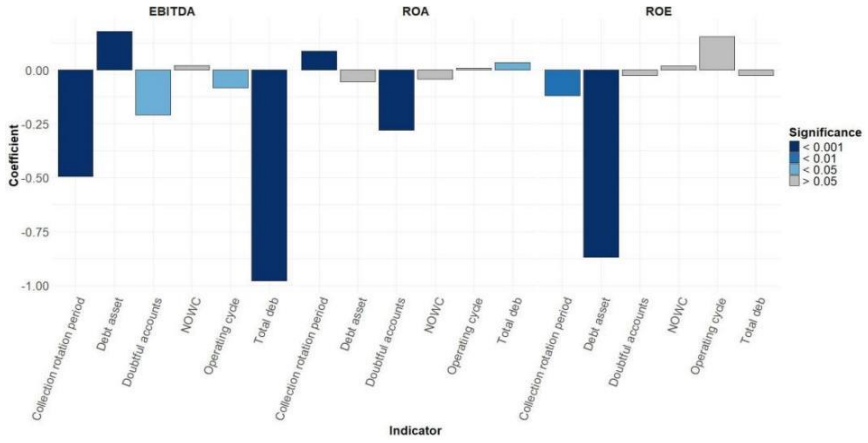

Figure 2. Coefficient by indicator and dependent variable Fixed Effects Model.

The following **(Figure 3)** show the result of the Random Effects model

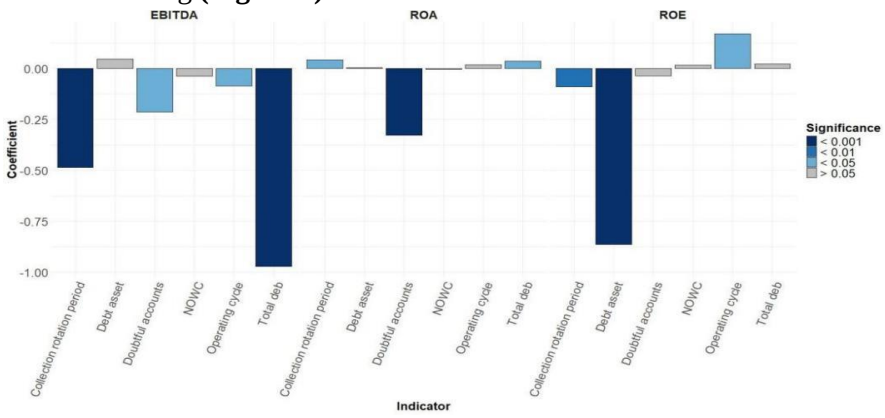

Figure 3. Coefficient by indicator and dependent variable Random Effects Model.

When validating hypotheses 1 and 2 for the ROA and ROE indicators under the adjusted models, it was found that these models adequately explain the variability of each indicator. The most important factors were the Operating Cycle for both indicators, and for ROE, the Debt Ratio and the Estimate of Difficult Debt Collection also played significant roles. In contrast, the adjusted models for EBITDA, tested under hypothesis 3, did not show a comparable fit to those for ROA and ROE. An example of this is the second model (M2), which exhibits a negative Adjusted R^2 as shown in **Table 1**, a critical indicator of the model's lack of predictive power. This suggests that the variables included in the models do not adequately cover the determinants of EBITDA. In addition, this indicator shows profit excluding interest, tax, depreciation and amortisation, which may lead to an overestimation of these items, as well as confusing liquidity, since it does not take into account changes in working capital, capital expenditure, inventories or accounts payable and receivable. Similarly, it does not measure the quality of profits or benefits and does not reflect a real cash flow.

5. Discussion

The results in **Table 1** show the statistical significance levels of 5%, 1% and 0.1%; the *F* test validates the M2 and M3 models; VIF values less than 5 rule out

multicollinearity. These findings differ from those of Batrancea (2021) who performed a correlation analysis between the independent variables that were represented with financial indicators such as ROA and EBITDA, among others. He determined that the highest correlation was the quick liquidity ratio with 0.52 and the lowest was the debt to equity ratio with 0.00, although the presence of multicollinearity was found when obtaining the data, this did not affect the estimated empirical results; these findings provide an opportunity to manage ratios and efficiency in healthcare entities. These results are in line with those of Lim and Rokhim (2021) who investigated the factors affecting the efficiency of healthcare and pharmaceutical entities in Indonesia, focusing on indicators such as ROE, ROA, showing their interactions with other indicators.

The results of the ROA models conclude that, for better performance, hospitals should focus their efforts on reducing the operating cycle, which allows for streamlining inventory management, collections, helps maintain control over debt, improving working capital and efficiency. This is consistent with the findings of Creixans and Arimany (2018) who argued that the efficiency of hospital entities requires a balanced distribution of assets, whether with own or third-party financing. Likewise, entities must have the capacity to meet short-term payments and an acceptable debt quality. They demonstrated the optimal economic situation of Spanish hospitals between 2008 and 2015, due to the performance and management carried out with assets and control of expenses. On the other hand, the findings in the study by Lee et al. (2019) were different and opposite, because the evaluation carried out on the financial indicators of the hospitals showed inefficient management, mainly due to an operational weakness and systematic differences in some ratios that demonstrate a lack of financial soundness, affecting the performance of these organizations.

Among the results associated with ROA with great significance is the operating cycle, showing that for study hospitals to achieve efficiency in the management of their resources, they have to reduce this indicator due to the great influence it has on accounts receivable, payable and inventories. To improve ROA, good handling and management of assets is recommended, because under international standards they must generate income and in accordance with the results, optimizing the operating cycle that can increase productivity, along with simplification of processes, modernization, better logistics capacity, training of employees, among others.

The result of the ROE models showed that a higher debt on assets has a positive impact when management control is adequate, which causes the debt to be favourable for the return. Hospitals must control their level of indebtedness, since a high one decreases efficiency; in addition, to improve the ROE it is necessary to reduce the operating cycle, these criteria coincide with the research of Turner et al. (2015) confirming that hospitals with a higher ROE have a greater efficiency and are substantially leveraged, they evaluated the factors that drive efficiency in American hospitals, finding that private health entities have higher profit margins and therefore a high ROE of (25%), while non- profit and public hospitals show a low ROE of 8% and 3% respectively. The efficiency in private hospitals is due to the operational processes and the generation of income; while in non-profit and public hospitals the low margins are due to the deficiency in the operating cycles and the lower amount of debt they use to finance the assets. In contrast to previous studies, the findings of

Guerra et al. (2022) argue that the level of indebtedness and the operating margin directly influence the efficiency of hospitals; the results were not as expected, their study was to determine the financial efficiency in Brazilian hospitals in the public system, which showed a continuous deficit and inefficiency, mainly due to low liquidity ratios, negative efficiency ratios and high levels of indebtedness, demonstrating a low level of performance due to internal and operational processes that must be rethought and improved.

Regarding the results associated with the ROE, it can be seen that indebtedness with respect to equity has a high impact, due to the onerous commitments that derive from it such as interest and financing expenses, a situation that in several cases was corrected by the intervention of Supersalud. To improve ROE, the capital structure must be optimized, seeking greater net profit and efficient management of it, along with growth and strategic expansion, and thus offering health services in remote places. Mechanisms must be sought to reduce operating expenses, making good use of economic resources, increasing the supply and provision of health services and thus increasing the net profit margin, which can be reinvested in innovation, research and improvement of the property, plant and equipment.

Finally, the results of the EBITDA models showed that hospitals must carefully manage their net working capital and reduce debt levels on assets and although operating cycle management is important in this scenario, its impact is less. This study agrees with the findings of Siedlecki et al. (2016) who concluded that rural hospitals in Poland, although small and with less income, have less debt than urban hospitals, which is why their financial situation is better. The operating cycle in rural hospitals does not show variation because it is within the range considered normal, for this reason, it does not present a significant impact. In relation to the above, Bernhard and Reto (2020) explain that to reduce debt levels on hospital assets, surpluses are required to develop assets, strategic plans and medical support and influence. The conclusions based on the results of the EBITDA models are aligned with the findings of Das et al. (2022) who inferred that in order to achieve a balance between working capital management and the financial health of hospitals in India after the Covid-19 pandemic, the capital gap is necessary with a deferred payment strategy, based on the fact that the operational activities of these health entities are financed by surpluses; therefore, the government must provide funds to improve efficiency and quality in the health service.

In short, hospitals that plan to improve their financial indicators must focus their efforts on optimizing their operating cycles, rigorously managing both their debt level and their working capital, taking into account that these guidelines allow for significant improvements in ROA, ROE and EBITDA. Similarly, “it is necessary to improve the public health service system, optimize the investment structure of medical and health resources, strengthen the preventive measures capacity of rural and community-based units, and strengthen the first line of defense” (Younis et al., 2021, p. 40367).

6. Conclusions

The results of the pooled OLS (M1), fixed effects (M2) and random effects (M3)

models, applied to the KPIs: ROA, ROE and EBITDA, reveal the following key findings:

ROA: A long operating cycle negatively affects the return on assets, suggesting that reducing it could optimize the use of assets in hospitals, generating greater resources in less time. A high ROA indicates efficient asset management, hence strategies such as reducing Doubtful accounts and maintaining a moderate debt level are essential to improving the operational and financial efficiency of hospitals in Colombia.

ROE: Debt and operating cycle indicators are key to this KPI, especially debt, which has a significant negative impact on capital efficiency. Prudent debt management and a short operating cycle are associated with better capital performance. This suggests that optimizing the capital structure and shortening the operating cycle could increase reinvestment and efficiency in Colombian hospitals, benefiting strategic areas such as R&D&I and improving the quality of health services.

EBITDA: Net working capital and debt-to-assets ratio negatively influence this ratio, the models adjusted for this KPI have lower predictive capacity compared to ROA and ROE hence the is not recommended. This indicates the need to adjust the models or incorporate additional variables to improve accuracy. A high EBITDA reflects a greater capacity to generate operating income; therefore, properly managing net working capital and debt-to-assets ratio could strengthen the financial stability and operational efficiency of hospitals.

In the current study, results of the statistical models on ROA ratio showed that, for better performance, hospitals must reduce the operating cycle, which streamlines inventory management and collections, controls debt, and improves working capital and efficiency. In turn, the statistical models on ROE ratio revealed that higher debt over assets has a positive impact when management control is adequate and favorable for return. In terms of validity of the models, it was found that the adjusted ones adequately explain the variability in ROA and ROE, but not in EBITDA ratio, hence the latter is not recommended to evaluate hospital efficiency reliably.

It is evident the need for urgent measures to improve the efficiency of highly complex public hospitals in Colombia, which serve vulnerable populations and play a fundamental role in guaranteeing the right to health, aligned with the UN 2030 Agenda. However, there is a lack of studies in the public hospital sector in Colombia; only four previous investigations (Arroyavez, 2001; Cárdenas and Velasco, 2014; Giménez et al., 2018; McPake et al., 2003) show deficiencies in management, high delinquency and low financial efficiency in these hospitals. Given this vulnerability, it is essential to implement administrative strategies that improve the efficiency and quality of service.

This study has limitations such as its six-year period and the exclusion of certain financial statements, which restrict its ability to capture long-term trends. Another limitation is data availability because, despite the application of IPSAS, there is no standard for the uniform presentation of accounting information by hospitals, which makes it difficult to categorize and organize data. On the other hand, the results of this study are only comparable with third-level or high-complexity hospitals, since the first and second-level hospitals that correspond to those of low and medium complexity, respectively, were not taken into account.

It is important to highlight that the results of a previous bibliometric and systemic study, carried out by our research group using the ProKnow C methodology, directed us to focus on public hospitals, an approach that coincides with the WHO and the OCDDE in that health has great relevance and significance in the budgets of the countries and therefore in government plans. Such plans are carried out by public hospitals because they serve those in need, manage public health crises, support research, health education, and contribute to the economic development of their communities (Cronin et al., 2022).

Future research should address the analysis of hospital efficiency with a longer time perspective, include post-COVID-19 variables, make comparisons between public and private hospitals. Furthermore, further studies should include public hospitals of first and second level of care or complexity, in which their installed capacity is analyzed and compared with the population served. its social impact and variables such as timeliness (care time), quality, conditions of health personnel, operational data of efficiency in services such as emergencies, intensive care, maternity, among others, are evaluated. Similarly, other studies should include patients through a classification system, such as Diagnosis-Related Groups (DRGs) that allow studying the efficiency of high-cost treatments, such as Human Immunodeficiency Virus (HIV), monkeypox, oncological, among others. Last but not least, health studies are necessary that focus on infrastructure and Research, Development, Innovation and Creation—(R+D+I+C). Note that the results of new research along the same lines as this study in developing countries may have implications for their health policies, because they are based on the need for regulatory updating that guarantees universal access to health services, affected by health crises, lack of funding, lack of technology, lack of research, among others (Creixans and Arimany-Serrat, 2018).

In Colombia and several developing countries and even in others that boast of being more technical and developed, a large number of public hospitals are in crisis; which justifies the need to update health policies, seeking to meet the Sustainable Development Goals SDGs and 2030 Agenda of the United Nations (UN) regarding health, mitigating the lack of resources and offering a greater opportunity for care in the face of the increase in demand for health care. This is why a coordinated approach in the allocation of resources and the development of public health policies tends towards efficient health systems and public hospitals, through centralized efforts in the provision of services and the replication of efficient models. With this, it is possible to both have a positive impact on medical care, the reduction of costs and health expenses and optimize its operation, all these aspects to be improved are work material and the beginning for new studies.

Author contributions: Conceptualization, RDC, CCS, VMRF and CAAM; methodology, RDC, CCS and VMRF; software, RDC; validation, RDC, CCS and VMRF; formal analysis, RDC, CCS and VMRF; investigation, RDC, CCS, VMRF and CAAM; resources, RDC; data curation, RDC; writing—original draft preparation, RDC, CCS, VMRF and CAAM; writing—review and editing, RDC, CCS and VMRF; visualization, RDC; supervision, RDC, CCS and VMRF; project administration, RDC, CCS and VMRF; funding acquisition, RDC. All authors have read and agreed to the

published version of the manuscript.

Conflict of interest: The authors declare no conflict of interest.

References

Amaral, M. (2024). Profitability of Commercial Banks in Portugal and Spain: A Panel Data Analysis Model. Revista de Métodos Cuantitativos Para La Economía y La Empresa, 1–18. https://doi.org/10.46661/rev.metodoscuant.econ.empresa.8172

Arroyavez, I. D. (2009). Preliminary formulation of a rational financial model for public hospitals (Spanish). Revista Facultad Nacional de Salud Pública, 19(2). https://doi.org/10.17533/udea.rfnsp.897

Banditori, C., Cappanera, P., & Visintin, F. (2013). A combined optimization-simulation approach to the master surgical scheduling problem. IMA Journal of Management Mathematics, 24(2), 155–187. https://doi.org/10.1093/imaman/dps033

Batrancea, L. (2021). The Influence of Liquidity and Solvency on Performance within the Healthcare Industry: Evidence from Publicly Listed Companies. Mathematics, 9(18), 2231. https://doi.org/10.3390/math9182231

Berger, M., & Tutz, G. (2018). Tree-Structured Clustering in Fixed Effects Models. Journal of Computational and Graphical Statistics, 27(2), 380–392. https://doi.org/10.1080/10618600.2017.1371030

Bernhard, E., & Reto, S. (2020). Strategies as a basis for the development of hospital assets. Public Money & Management, 40(1), 21–30. https://doi.org/10.1080/09540962.2019.1612204

Bonhomme, S., & Davezies, L. (2019). Panel Data, Old and New. Annals of Economics and Statistics, 134, 1. https://doi.org/10.15609/annaeconstat2009.134.0001

Bosa, I. M. (2010). Ethical budgets: a critical success factor in implementing new public management accountability in health care. Health Services Management Research, 23(2), 76–83. https://doi.org/10.1258/hsmr.2009.009024

Cárdenas G., M., & Velasco B., et al. (2014). Incidence of accounts receivable delinquency on profitability and liquidity: a case study of a Empresa Social del Estado health services provider (Spanish). Revista Facultad Nacional de Salud Pública, 32(1), 16–25. https://doi.org/10.17533/udea.rfnsp.15182

Creixans, J., & Arimany-Serrat, N. (2018). Influential variables in the profitability of hospital companies. Intangible Capital, 14(1), 171. https://doi.org/10.3926/ic.1109

Cronin, C. E., Singh, S. R., Turner, J. S., & Evashwick, C. J. (2022). Hospitals' contributions to their communities: Should they be regulated?. Frontiers In Public Health, 10, 1-4. https://doi.org/10.3389/fpubh.2022.1064210

Das, S. L., Patnaik, B. C. M., Satpathy, I., et al. (2022). Working capital management and financial health of private hospitals of India after COVID-19 pandemic. International Journal of Health Sciences, 1911–1922. https://doi.org/10.53730/ijhs.v6ns5.9043

Ekiz Bozdemir, M. K., Avcı, S., & Aladağ, Z. (2023). Assessment of the Turkish Health Transformation Program with Data Envelopment Analysis. IEEE Transactions on Engineering Management, 70(8), 2800–2808. https://doi.org/10.1109/tem.2021.3106581

Eldenburg, L., & Krishnan, R. (2006). Management accounting and control in healthcare: an economic perspective. Handbooks of management accounting research, 2, 859-883. https://doi.org/10.1016/S1751- 3243(06)02016-5

Esposito, R., Cerrato, M., & Locatelli, M. (2024). Partitioned least squares. Machine Learning, 113(9), 6839–6869. https://doi.org/10.1007/s10994-024-06582-3

Fiondella, C., Macchioni, R., Maffei, M., et al. (2016). Successful changes in management accounting systems: A healthcare case study. Accounting Forum, 40(3), 186–204. https://doi.org/10.1016/j.accfor.2016.05.004

Ghandour, Z., Siciliani, L., & Straume, O. R. (2022). Investment and quality competition in healthcare markets. Journal of Health Economics, 82, 102588. https://doi.org/10.1016/j.jhealeco.2022.102588

Giménez, V., Prieto, W., Prior, D., et al. (2019). Evaluation of efficiency in Colombian hospitals: An analysis for the post-reform period. Socio-Economic Planning Sciences, 65, 20–35. https://doi.org/10.1016/j.seps.2018.02.002

Guerra, M., Morgan, B.F., & Alves, M.C. (2022). Financial Performance and Profile of Brazilian Hospitals. Journal of Health Management, 24(2), 175-186. https://doi.org/10.1177/09720634221088056

Guimaraes, A. L. de S., & Nossa, V. (2010). Working capital, profitability, liquidity and solvency of healthcare insurance companies. Brazilian Business Review, 7(2), 37–59. https://doi.org/10.15728/bbr.2010.7.2.3

Hammad, S. A., Jusoh, R., & Yen Nee Oon, E. (2010). Management accounting system for hospitals: a research framework. Industrial Management & Data Systems, 110(5), 762–784. https://doi.org/10.1108/02635571011044777

Hill, T. D., Davis, A. P., Roos, J. M., et al. (2019). Limitations of Fixed-Effects Models for Panel Data. Sociological Perspectives, 63(3), 357–369. https://doi.org/10.1177/0731121419863785

Jacob, J., & Varadharajan, R. (2024). Robust Variance Inflation Factor: A Promising Approach for Collinearity Diagnostics in the Presence of Outliers. Sankhya B, 86(2), 845–871. https://doi.org/10.1007/s13571-024-00342-y

Kalnins, A., & Praitis Hill, K. (2024). Additional caution regarding rules of thumb for variance inflation factors: extending O'Brien to the context of specification error. Quality & Quantity. https://doi.org/10.1007/s11135-024-01980-0

Kraus, K., Kennergren, C., & von Unge, A. (2017). The interplay between ideological control and formal management control systems – A case study of a non-governmental organisation. Accounting, Organizations and Society, 63, 42–59. https://doi.org/10.1016/j.aos.2016.02.001

Lee, D., Yu, S., & Yoon, S. N. (2019). Analysis of Hospital Management based on the Characteristics of Hospitals: Focusing on Financial Indicators. Global Business Finance Review, 24(3), 1–13. https://doi.org/10.17549/gbfr.2019.24.3.1

Lim, H., & Rokhim, R. (2020). Factors affecting profitability of pharmaceutical company: an Indonesian evidence. Journal of Economic Studies, ahead-of-print(ahead-of-print). https://doi.org/10.1108/jes-01-2020-0021

Llewellyn, S., Eden, R., & Lay, C. (2005). Costs, incentives and changing resource allocations in health care organisations: comparing the UK and Canada. Journal of Accounting & Organizational Change, 1(1), 79–95. https://doi.org/10.1108/18325910510635308

Macinati, M. S., & Rizzo, M. G. (2016). Exploring the link between clinical managers involvement in budgeting and performance. Health Care Management Review, 41(3), 213–223. https://doi.org/10.1097/hmr.0000000000000071

McKenzie, J. E., & Veroniki, A. A. (2024). A brief note on the random-effects meta-analysis model and its relationship to other models. Journal of Clinical Epidemiology, 174, 111492. https://doi.org/10.1016/j.jclinepi.2024.111492

McPake, B. (2003). Is the Colombian health system reform improving the performance of public hospitals in Bogota? Health Policy and Planning, 18(2), 182–194. https://doi.org/10.1093/heapol/czg023

Meredith, J. O., Grove, A. L., Walley, P., et al. (2011). Are we operating effectively? A lean analysis of operating theatre changeovers. Operations Management Research, 4(3–4), 89–98. https://doi.org/10.1007/s12063-011-0054-6

Moons, K., Waeyenbergh, G., & Pintelon, L. (2019). Measuring the logistics performance of internal hospital supply chains – A literature study. Omega, 82, 205–217. https://doi.org/10.1016/j.omega.2018.01.007

Nyland, K., Morland, C., & Burns, J. (2017). The interplay of managerial and non-managerial controls, institutional work, and the coordination of laterally dependent hospital activities. Qualitative Research in Accounting & Management, 4(4), 467-495. https://doi.org/10.1108/QRAM-08- 2017-0076

Popesko, B., Novák, P., & Papadaki, S. (2015). Measuring diagnostics and patient profitability in healthcare: Economics vs. Ethics. Economics and Sociology, 8(1), 234-245. https://doi.org/10.14254/2071-789X.2015/8-1/18

Purbey, S., Mukherjee, K., & Bhar, C. (2007). Performance measurement system for healthcare processes. International Journal of Productivity and Performance Management, 56(3), 241–251. https://doi.org/10.1108/17410400710731446

Ramanathan, R. (2005). Operations assessment of hospitals in the Sultanate of Oman. International Journal of Operations & Production Management, 25(1), 39–54. https://doi.org/10.1108/01443570510572231

Salmerón-Gómez, R., García-García, C. B., & García-Pérez, J. (2024). A Redefined Variance Inflation Factor: Overcoming the Limitations of the Variance Inflation Factor. Computational Economics, 65(1), 337–363. https://doi.org/10.1007/s10614-024-10575-8

Siedlecki, R., Bem, A., Ucieklak-Jeż, P., et al. (2016). Rural Versus Urban Hospitals in Poland. Hospital's Financial Health Assessment. Procedia - Social and Behavioral Sciences, 220, 444–451. https://doi.org/10.1016/j.sbspro.2016.05.519

Turner, J., Broom, K., Elliot, M., & Lee, J. (2015). Decomposition of Hospital Profitability: An Application of DuPont Analysis to the US Market. Health services research and managerial epidemiology, 1-10. https://doi.org/10.1177/2333392815590397

Van Erp, W., Roozen, F., & Vosselman, E. (2019). The performativity of a management accounting and control system: Exploring the dynamic relational consequences of a design. Scandinavian Journal of Management, 35(4), 101077. https://doi.org/10.1016/j.scaman.2019.101077

Younis, I., Longsheng, C., Zulfiqar, M. I., et al. (2020). Regional disparities in Preventive measures of COVID-19 pandemic in China. A study from international students' prior knowledge, perception and vulnerabilities. Environmental Science and Pollution Research, 28(30), 40355–40370. https://doi.org/10.1007/s11356-020-10932-8