A DEA Approach for measuring healthcare efficiency in medical, clinical and obstetric specialties

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Abstract

Alagoas occupies the worst public health positions in Brazil, and first in the indicators of infant mortality, presenting an extremely high mortality rate (48.2 deaths per thousand live births to a Brazilian average of 26.3 deaths per thousand live births). Such problem highlights the need for quantitative methodologies in order to evaluate the technical efficiency of state health units in search of continuous improvement of their results. The present study develops an efficiency analysis of several public and private hospitals located in the state of Alagoas using the Data Envelopment Analysis (DEA) as a tool, aiming to obtain efficiency indices to support the decision making of public agents. The data used refer to the period from August 2018 to July 2019, in which the specialties of Medical Clinic, Surgical Clinic and Obstetrics were selected to compose the analysis inputs and outputs. The evaluation brings considerations and contributions regarding the public health problem in the state and in the country.

Keywords

efficiency, public health, hospitals, healthcare, Data Envelopment Analysis, Alagoas.

1. Introduction

Hospitals are corporations that present extreme entanglements regarding their management, especially due to the attribute of grouping different amenities and occurrences in parallel (Celestino, 2002). Through the management of the set of employees, financial management and available assets in general, hospitals are defined as organizations that present turbulence. That is, they work together in several segments, addressing essential elements aimed at the provision of health-related services. These factors directly affect the efficiency of a hospital service (Mendes, 1998).

Lately, hospitals have not been bearing good fruit, especially through government practices. In the circumstance that they have a duty to improve health, mainly because they have a high demand for care, however, they have a scarcity of accessible funds, thus, this scenario becomes disturbing (Souza, 2012). Despite being a primordial element in Brazilian health, hospital entities, until recently, did not have a large concentration of explorers on the subject (La Forgia; Couttolenc, 2009).

Through the incessant searches of the inhabitants of Alagoas for care in hospital urgent/emergency services (SUH), this factor has contributed significantly to a growing adversity of overcrowding, being one of the most seen problems of the Unified Health System (Sistema Único de Saúde - SUS). In addition, Alagoas has occupied one of the worst positions in the ranking in Brazilian public health, and has been the leader in infant mortality, with extremely expressive numbers compared to other states (48.2 deaths per thousand live births for a Brazilian average of 26.3 deaths per thousand live births).

Ayres (2019) argues that there should be a more comprehensive action by the citizens of Alagoas and the academic scenario in retaliation for the lack of government investments in public health in Alagoas, especially in the construction of public hospitals, which aim to meet all the demand of the population in question, further reinforcing the Unified Health System (Sistema Único de Saúde - SUS) in different locations of the state, seeking to reach the largest number of people residing in the state with coverage of basic health services.

Data Envelopment Analysis (DEA) is a highly effective instrument to obtain a sampling of the efficiency of hospital circumstances. It is illustrated as a mechanism that assists in modeling, being contextualized through the researchers: Rhodes, Cooper and Charnes (1978) in the mid-70s. It was developed by Farrell (1957), who was a pioneer in the subject, developing a method for measuring the performance of different organizations, as well as the behavior of hospitals, aided by linear programming. According to Souza et. al. (2006), DEA distinguishes itself as one of the most effective methods of estimating efficiency, mainly because it offers alternatives to make the most appropriate decisions. In addition, it is possible to measure the perspectives of different inflows and outflows, identifying the appropriate currency internally, in addition to establishing results aimed at the inefficiency of its subdivisions.

It is extremely relevant to analyze hospital efficiency, especially because it brings possibilities for administrators to use the results of evaluations as a way to examine the deficits found in hospital services, build a plan for new movements and determine preferences. From DEA assessments and results, hospital managers have the possibility of monitoring the activities and the possibility to assess the functioning of the hospital institution and access best practices for continuous improvements (Nepomuceno et al 2020, 2022; Wolff, 2005).

Therefore, the main objective of the present study is to analyze the efficiency of hospital entities in the state of Alagoas, based on the use of the computational modeling tool Data Envelopment Analysis (DEA). For the construction of the study, the following particularities were separated for the analysis: Medical Surgical Clinic and Obstetrics. Hospitalization data (total number, total expenditures and average length of stay in hospitalization) were used as inputs, and mortality rate was used as outputs, which is seen in reverse as the success rate.

2. Literature Review

The health area is one of the indispensable areas for the use of the DEA tool. Mainly due to the fact that it obtains a verification on a long investigative scale related to organizations from various segments, such as public and private hospitals. Three great researchers on the subject were the scholars Sheman, Charnes and Nunamaker, who were the forerunners of this research. It was through the studies of Charnes that it became possible to analyze the efficiency of several organizations and different institutions, through the DEA technique, where each segment is verified one after the other. Thus, the way to optimize a respective unit is determined through its inputs.

In the works developed by Mello (2005), Data Envelopment Analysis is defined as a tool that aims to be used through computational mechanisms to be analyzed as decision-making practices (Decision Making Units - DMU), with the objective of obtaining efficiency of the organizations or institutions examined.

According to Colin (2013), Boundary Analysis is seen as a tool that has a wide applicability and is easy to use, where it aims to solve several problems encountered today. In addition, it is possible to obtain a related comparison between inputs and outputs through the efficiency of the environment in question, constituting signs of possible improvements.

2.1. Efficiency Analysis

In the studies by Gomes and Ponchio (2005), the technical efficiency of a given singularity is measured through some parameters that act as measuring practices with the objective of confronting the analyzed values in question. In addition, this confrontation is determined by means of the allegation under analysis and the extreme production, in relation to the data that are available for use. Therefore, whatever the interpellation under analysis, the efficiency obtained will always be equal to 1. That is, when an established unit has a score equal to 1, this result shows that it is compliant, presenting the highest value of technical efficiency that can be achieved.

Efficiency analysis can be explored on different occasions, such as through the DEA (Data Envelopment Analysis) tool. This methodology offers a survey of efficient borders, which will be used as representations for possible comparisons between the investigated data (Encinas, 2010), portrays that Data Envelopment Analysis (DEA) is a method that has a qualitative and quantitative appearance, and is also a methodology that analyzes different factors obtaining a high level of satisfaction with its use, resulting in diversified DMU's reaching the highest efficiency score.

In the circumstances of this work, it is intended to verify the efficiency of 64 public and private hospitals located in Alagoas, offering an improvement in the effectiveness of the analyzed locations, using Data Envelopment Analysis as the methodology of comparison and analysis.

2.2. Data Envelopment Analysis (DEA)

The application of Data Envelopment Analysis is employed to establish technical efficiency in divergent circumstances, and has become overused (Cooper et al., 2007). In agreement with this contextualization, one of the main explanations for its rationale is that the DEA acts in a way that generates satisfaction with its use, especially because it offers a mechanism that is easy to handle and has satisfactory consequences (Souza et al., 2014).

The DEA tool detects an effective limit of DMU's using the higher actions, and it is possible to use this information to estimate the efficiency ratio of inefficient DMU's (Azadeh, 2009). In these circumstances, one of the main benefits that this method offers is that unfit DMU's are pitted against other effective DMU's (Giannakis et al., 2005).

Taking into account a grouping of d decision-making units (DMU) in which each element j = 1, 2, 3..., d using i = 1, 2, ..., n inputs to operate r = 1, 2, ..., m solutions (outputs), the possible gaps in the inputs s_i and the results s_r can be defined by linear contraction in the input oriented model [BANKER et al. 1984; COOPER et al. 2006; ZHU 2014]:

$$\max \sum_{i=1}^{n} s_i + \sum_{r=1}^{m} s_r$$

Subject to:

$$\sum_{j=1}^{d} \lambda_j x_{ij} - \theta^* \, x_{io} + s_i = 0 \qquad \textbf{(1)}$$
$$\sum_{j=1}^{d} \lambda_j y_{rj} - (y_{ro} + \boldsymbol{s_r} \ ) = 0$$
$$\sum_{j=1}^{d} \lambda_j = 1$$
$$\lambda_j \geq 0$$

The related space between the unfit pseudo-unit and its efficiency parameter symbolizes the clearances defined through the manufacturing activity of the elements in the production system considered in approximate proportions of inputs and outputs (Sherman and Zhu, 2006; Cooper et al., 2006).

3. Data and Methodological Procedures

To carry out the present work, a bibliographic research was initially carried out on the themes in question, seeking the most renowned authors and especially researchers who have recently developed research. Based on this, the study is an exploratory investigation, with interpellations determined in amounts, conducted in 64 public and private hospitals, located in different regions of Alagoas. In relation to the size of the hospital entities in question, they are diversified, with small, medium and large hospitals. In addition, it is intended to expose, through the modeling tool Data Envelopment Analysis (DEA), the aspects that clarify the efficiency rates in the hospitals in question.

With regard to the verification mechanisms, a data search was carried out with the objective of finding records with hospital information in the region of Alagoas. Therefore, the data necessary to carry out the study were obtained from official websites that provide indices and consequently consequences in the hospital context (DATASUS, Ministry of Health, and

CNES). For the execution of the DEA, the first stage was to determine how many and which elements would be established as inputs and outputs, especially because it is one of the most relevant stages during the execution of the research. The following particularities were selected for the analysis: Medical, Surgical and Obstetric Clinics. Thus, the total expenditure on hospitalizations was established as an input, and the number of hospitalizations per health unit was used as an output. The items were chosen according to the availability of information, so that comparisons could be made.

Figures 1, 2 and 3 illustrate Boxplots with some descriptive statistics of the dataset. In this representation, the mortality rate of each specialty is used as a way to stipulate success. Over the course of a sufficiently large period for hospitalization data, such as one year, two outcomes are possible for each hospitalization: death or discharge from the hospital (success). Thus, success as output is defined as all cases of hospitalizations for a given specialty minus deaths.

The average obtained in the investigated parameters of the specialty of Clinical Surgery were: an average of 917.3 people, an average stay of 2 days, a total average value of R$ 136,408.00, and a success rate of 904.1%. In the Internal Medicine section the following results were found: an average of 665.91 hospitalizations, the average length of stay was 3 days, an average value of R$124,964.07 and, finally, a success rate of approximately 585.38%. In the specialty of Obstetrics, they were examined using the same parameters determined before. Thus, the following consequences were followed: An average of 740 hospitalizations, the average length of stay was 5 days, an average value of R$107,611.2, and finally, a success rate of 739.8% was obtained.

Figure 1. Descriptive Boxplot for Internal Medicine: Hospitalizations, Average Stay, Total Value of Hospitalizations and Success Rate.
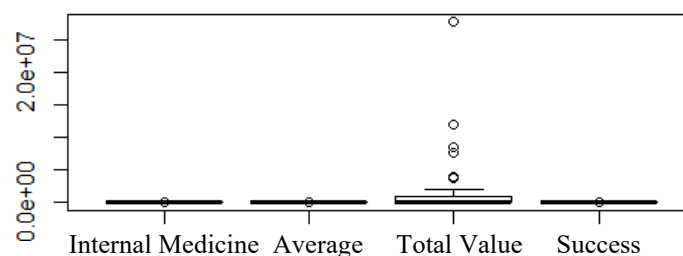

Figure 2. Descriptive Boxplot for Surgical Clinic: Hospitalizations, Average Stay, Total Value of Hospitalizations and Success Rate.
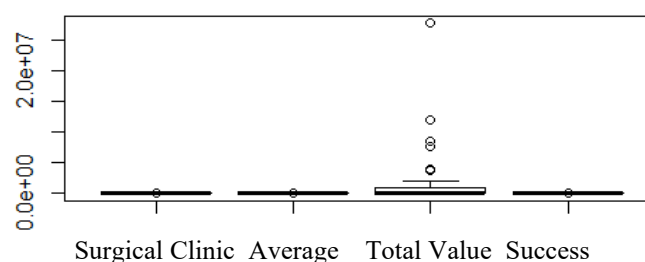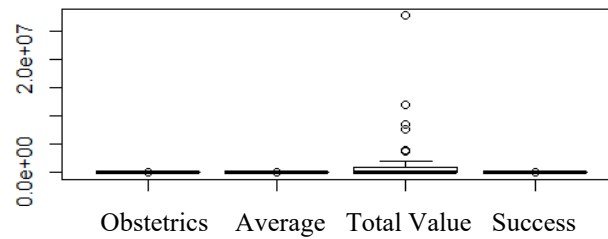
Figure 3. Descriptive Boxplot for Obstetrics: Hospitalizations, Average Stay, Total Value of Hospitalizations and Success Rate.

4. Results and Discussions

The medical specialties to be analyzed using Data Envelopment Analysis (DEA) were Internal Medicine (50 hospitals), Surgical Clinic (33 hospitals) and Obstetrics (43 hospitals), in 3 input oriented models with variable returns of scale where the total value of hospitalizations and the number of hospitalizations in 2019 were used as parameters. Table 1 shows the main results.

Table 1. Results of the Hospital Efficiency Analysis in the Three Models

Efficiency Range	Medical Clinic Template		Surgical Clinic Model		Obstetrics Model	
	Hospitals	Percentage	Hospitals	Percentage	Hospitals	Percentage
0.1<= E <0.2	-	-	5	15.2	-	-
0.2<= E <0.3	4	8	1	3.0	-	-
0.3<= E <0.4	4	8	2	6.1	-	-
0.4<= E <0.5	7	14	5	15.2	-	-
0.5<= E <0.6	7	14	2	6.1	-	-
0.6<= E <0.7	8	16	2	6.1	1	2.3
0.7<= E <0.8	7	14	2	6.1	1	2.3
0.8<= E <0.9	4	8	3	9.1	18	41.9
0.9<= E <1	3	6	5	15.2	18	41.9
E ==1	6	12	6	18.2	5	11.6

The number of efficient hospitals in the analysis of hospitals operating the specialties of internal medicine, surgery and obstetrics was 6 units (12% of the total of 50 hospitals), 6 units (18.2% of the total of 33 hospitals) and 5 units (11.6% of the total of 43 hospitals). The specialty of internal medicine has the lowest average efficiency in Alagoas (0.641), while the specialties of clinical surgery and obstetrics have the largest difference in efficiency interval (minimum efficiency of 0.1107, 0.8893 interval) and highest average efficiency (0.898), respectively.

These results show that Alagoas is a considerably inefficient state, with an average capacity for improvement of 27.2% in its hospitalizations (driven by a low average efficiency in the specialty of internal medicine, of which 35.9% can be improved). These improvements can be reflected, for example, in the increased response capacity of these hospitals to Covid-19 cases with the allocation of beds and idle resources through benchmarking of best practices in reference hospitals for efficiency. These health units are represented in Figures 4, 5 and 6 as the points that are located on the contour of the efficiency frontier, enveloping the other health units in the state.

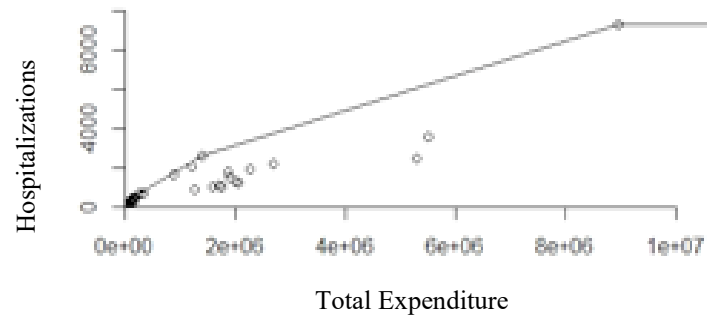Figure 4. Efficiency Frontier (Internal Medicine)

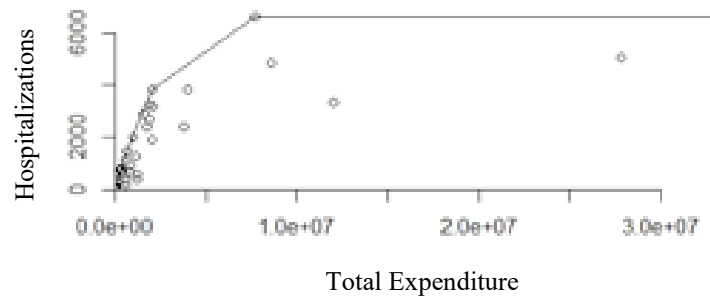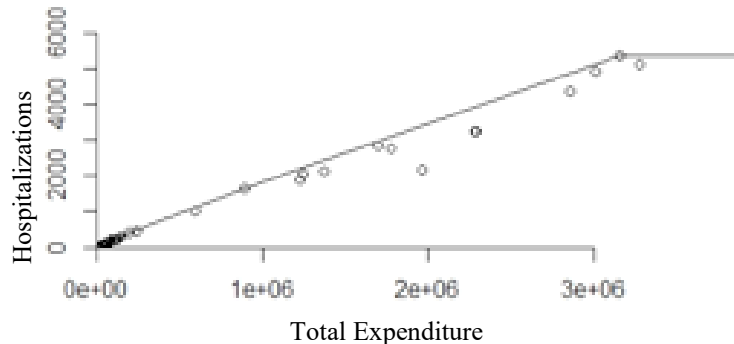

Figure 5. Efficiency Frontier (Surgical Clinic).

Figure 6. Efficiency Frontier (Obstetrics).

Such hospitals that are on the margin of technical efficiency are described below. As for the Internal Medicine specialty, the reference health units of efficiency are: Hospital Sanatório, Hospital Geral do Estado Dr. Osvaldo Brandão Vilela, Hospital Nossa Senhora de Lourdes and Maternidade Armando Lages, Unidade Adelia Abreu Vilar, Unidade Hospitalar de Quebrangulo and Hospital Nossa Senhora da Guia. As for the Clinical Surgical specialty, the efficient hospitals that serve as references for best practices in the management of hospitalizations are: Santa Casa de Misericórdia de Penedo, Hospital Geral do Estado Dr. Osvaldo Brandão Vilela, Hospital Municipal Dr. José Vanio de Barros Morais, Unidade Mista Dr. Djalma Gonçalves dos Anjos, Hospital Geral Dagoberto Omena (HGDO) and Hospital

Médico Cirúrgico. For the specialty of Obstetrics, efficient hospitals are: Santa Casa de Misericórdia de Penedo, Unidade Mista Dr. Djalma Gonçalves dos Anjos, Unidade Adélia Abreu Vilar, Unidade Hospitalar de Quebrangulo and Hospital Regional Dr. Clodolfo Rodrigues de Mello.

On the other hand, in order for inefficient hospitals to be able to achieve the highest efficiency score compared to others, it is necessary that there is a greater number of investments by the government in public hospitals, while in private hospitals, it is essential that managers draw up a plan to improve the services provided, in addition, that they purchase equipment in general and value the training of employees so that they can provide the best services to the public. necessary services that the population demands. In addition, it is also ideal to hire qualified professionals who perform their functionalities successfully, offering a fast and efficient service, consequently minimizing the mortality rate in a beneficial way.

5. Conclusions

In this work, an analysis of the efficiency of public and private hospitals located in Alagoas was proposed, where the computational modeling tool - Data Envelopment Analysis (DEA) was used as an aid. To this end, it was decided to use data on hospitalization expenditures as inputs, and hospitalizations as results of this investment.

It was found that the specialty of Clinical Surgery was the one that stood out the least in the efficiency items analyzed. This specialty should draw the attention of public authorities to greater investments, as it demands exceptional care in ICA (Intensive Care Units) beds that can be better managed with good management practices. In addition, 6 of the 50 hospitals analyzed for the medical specialty, and of the 33 surgical hospitals and 5 of the hospitals among the 43 that operate with the speciality of obstetrics obtained a score equal to 1, that is, they are technically efficient and should serve as references for these best practices. Such hospitals are presented in section 4 of this paper.

Therefore, the use of the Data Envelopment Analysis (DEA) tool was extremely beneficial for the performance of the present study, especially because it obtained a wide breadth, applicability and adaptability in judging different items with regard to data related to the health area. From this, during the period from August 2018 to July 2019, it was possible to analyze the efficiency of public and private hospitals located in Alagoas, taking into account criteria such as average hospitalizations, stay, total amount spent and success rate.

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Conflict of Interest Declaration

The authors have no conflicts of interest to declare. All co-authors have seen and agree with the contents of the manuscript and there is no financial interest to report.

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