PERFOMANCE MANAGEMENT OF PERNAMBUCO'S INTEGRATED SECURITY AREAS: AN APPROACH BASED ON DEA

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RESUMO

Vinte e seis áreas integradas de segurança (AIS) foram selecionadas como objetos de estudo e uma variável de entrada e quatro variáveis de saída foram filtradas como medidas de avaliação. Um modelo de análise por envoltória de dados foi utilizado para a avaliação de desempenho. Os resultados evidenciaram que (1) os valores médios de eficiência foram perto de 0,9; (2) cerca de 60% das áreas eficientes estão localizadas no sertão de Pernambuco; (3) AIS-20 é a referência para cerca de 61% das áreas ineficientes; e (4) AIS-10 apresenta o pior escore de eficiência. Finalmente, uma sugestão principal é defendida: os gestores devem considerar a hipótese de que características socioeconômicas da região bem como as operações das unidades de produção podem influenciar os escores de eficiência.

Palavras-chave. Análise eficiência, DEA, Áreas Integradas de Segurança (AIS).

Área principal: DEA - Data Envelopment Analysis, PO em Gestão Pública

ABSTRACT

This study aimed to conduct a performance evaluation of Pernambuco's integrated security areas (ISAs) and also to propose suggestions for performance improvement. In this paper, 26 ISAs were selected as study objects, and one input variable and four output variables were filtered as evaluation measures. A data envelopment analysis model was used for performance evaluation. The results evidenced that (1) the mean efficiency values were close to 0.9; (2)about 60% of efficient areas are located in Pernambuco's countryside; (3) ISA-20 is the benchmark for approximately 61% of inefficient areas; and (4) ISA-10 presents the worst efficiency score. At last, one main suggestion is advocated: managers should consider how socioeconomic features of the region and the operations of the production units could influence the efficiency scores.

KEYWORDS. Efficiency Analysis, DEA, Integrated Security Areas (ISA).

Main Area: PO in Public Management, DEA – Data Envelopment Analysis

1. Introduction

In 2012, more than 10% of homicides in the world happened in Brazil. The homicide rate in the country was 25.2 murders per 100,000 inhabitants. This number was six times the world average, 6.5 homicides per 100,000 inhabitants, and classified the country at 16th in the ranking of the most violent countries in the world, according to the Global Study on Homicide drafted in 2013 by the United Nations Office on Drugs and Crime (UNODC).

In order to settle this scenario, some states have developed public policies in recent years. The Pact for Life is an example of a program that is part of a public safety policy developed in Pernambuco, the second most populous state in the northeastern part of Brazil, in 2007. According to Ratton et al. (2014), it was based on:

- The relationship between public safety and human rights;
- The incorporation of all levels of security policy management mechanisms;
- The relationship between reconciling the repression qualified for the specific prevention of crime and violence;
- Monitoring and evaluation;
- Participation and social control since the formulation of strategies until the implementation of policy;
- The relationship among mainstreaming and integrating actions for public safety;
- The priority of combating intentional lethal violent crime (ILVC)[1]; and
- The goal of reducing the rate of ILVC by 12% per year in Pernambuco.

The program was successful in combating the homicide rates, which were reduced by almost 40% from 2006 to 2013, according to the Social Defense Department of Pernambuco. The Pact for Life won an award for public management by the United Nations in 2013 and, more recently, it was awarded in the category “Government Insurance: Good Practices in Crime and Violence Prevention” by the Inter-American Development Bank.

As an incentive to reach the main goal, i.e., reduce the rate of ILVC by 12% per year, public managers created police operations focused on seizures of drugs, weapons, and offenders. The Office of Public Administrator was also created to, among other things, monitor and compare police units’ (civil police stations and military police battalions) participation in these operations. These units were arranged in 26 integrated security areas around the state, which were created based on the size of the municipalities and the populations of each one. The managers use the Integrated Security Areas (ISAs) to make comparisons and reward the unit that functions in the most outstanding areas.

The issue is that the comparison between these units is made only in terms of productivity. The manner in which the several inputs are combined to produce the several required outputs, i.e., the efficiency of the integrated security areas, is not measured. This work will obtain measures for the efficiency of the integrated areas.

In the literature, the concern over the efficiency measures emerged in the 1970s (for more details, see the work of Ostrom, 1973; Skogan, 1976; Bodily, 1978). This technique has been used not only in the area of public safety but also in several other areas of public administration, and some papers have used this technique combined with clustering methods or regression methods to analyze the efficiency scores.

One of the main quantitative approaches for examining the efficiency is data envelopment analysis (DEA) and several papers have used this approach. Yeh and Cheng (2013) selected 28 national hospitals in Taiwan to conduct a study which aimed to evaluate changes in operating performances of these hospitals during the period 2005–2008 as well as to propose

[1] Intentional lethal violent crimes (ILVC) refers to the sum of homicides, injury followed by death and robbery followed by death, i.e., this variable represents the amount of crimes against life.

suggestions for operating performance improvements. The authors used a data envelopment analysis model for annual operating performance evaluation and the Malmquist productivity index for intertemporal operating performance change analysis. In addition, a performance scatter diagram and a strategy management matrix were utilized to synthetically analyze all kinds of operation performance data and, accordingly, improvement suggestions were proposed.

Carboni and Russu (2014) used DEA to evaluate the wellbeing performance of the 20 Italian regions from 2005 to 2011. They studied 12 indicators that represented different aspects of wellbeing. Furthermore, they used a self-organizing map technique to cluster regions into homogeneous clusters.

Regarding crime and violence, Sun (2002) used data envelopment analysis to study the efficiency of 14 police precincts units in Taipei, Taiwan. Drake and Simper (2000; 2003) conducted two similar studies in English and Welsh police forces. Diez-Ticio and Mancebon (2010) studied the efficiency of Spanish police in relation to solving crimes. On the other side of things, Grubesic et al (2012) used DEA methodology to investigate the link between violent crime and social disorganization. In Brazil, Melo et al (2005) measured the efficiency of the ISA in the State of Rio de Janeiro using DEA. In Minas Gerais, Scalco et al (2012) used the same method to evaluate the efficiency of the military police of that state. Moreover, they progressed in investigating factors that could influence this efficiency. Santiago et al. (2014) obtained the efficiency of 150 police stations in Pernambuco using DEA. They investigated factors that could influence this efficiency using a regression model. Meza et al. (2014) used DEA to estimate efficiency scores of the pacifying police units located in Rio de Janeiro. These units were located in communities and were part of a new security public model development which aimed to reduce criminality and approximate police and people.

The objective of this paper is to create a measure for the ISA and to analyze the scores to generate management information. For this, we used DEA to obtain efficiency scores. The total amount of civil and military police forces working in these areas was inputted into the model. The products were the amount of firearms seized by ISA, the amount of converted crack seized by ISA, and the amount of people arrested and imprisoned, while the inverse of the rate of intentional lethal violent crimes (ILCV) variable was used as a proxy for the effectiveness of ISAs. These variables, except for ILVC, have been used by the Center for the Management of the Social Defense Department of Pernambuco to assess the efficiency of the civil and military police battalions in the integrated security areas.

The next section summarizes the methodology (DEA) used to measure the efficiency of police, the data and variables. In the third section, we analyze the data and present the results of the DEA. Finally, forth section presents the conclusions.

2. Methodology

This section describes the methods used in this work. First, we present data envelopment analysis. In 2.2, the areas, the data, and the variables (input and output) used are described.

2.1 Data Envelopment Analysis (DEA)

As we mentioned, the efficiency of 26 integrated security areas of Pernambuco State was estimated by DEA. In this analysis, ISAs are considered decision-making units (DMUs), which are evaluated by their relative efficiencies that comprise the efficient frontier. In DEA, DMUs perform similar activities, differing by the amount of inputs they consume and the outputs obtained.

The DEA method is inserted into the nonparametric approach and makes use of mathematical programming in an estimation. This method was based on work by Farrell (1957) and subsequently popularized by Charnes et al. (1978). The DEA model characterized by constant returns to scale (the CCR model) can be summarized assuming *n* DMUs using *m* inputs to produce *s* products. Specifically, the index *j* indicates the *j-th* DMU for which $□_{□□}$ and $□_{□□}$ vectors represent the quantity of inputs (*i*) consumed and outputs (*r*) produced. The goal is to build a nonparametric frontier that envelops the data so that all units are on or below this boundary. This model can be described with the following equation:

$$□□□_{□,□}\,□ \qquad (1)$$

$$□.□$$
$$-□□_{□} + □□ \geq 0,$$
$$□_{□} - □□ \geq 0,$$
$$□ \geq 0$$

As can be seen in Sampaio and Melo (2008), the use of the CCR model can result in technical efficiency measures influenced by measures of scale efficiency when not all DMUs are operating at optimal scale. In such cases, the approach of the varying returns scale (BCC) allows solving this problem, i.e., measuring the interference effectively without technical scale efficiency. This approach, proposed by Banker et al (1984), adds a convexity constraint. In this case, for each DMU, the ratio between the weighted sum of the products and the weighted sum of the inputs is maximized. This model can be described with the following equation:

$$□□□_{□,□}\,□ \qquad (2)$$

$$□.□$$
$$-□□_{□} + □□ \geq 0,$$
$$□_{1}\,□ = 1,$$
$$□ \geq 0$$

where N_1 is a vector (Nx1) of unit numbers (1,..., 1).

Furthermore, these models can be divided into two types: input-oriented models, which seek to minimize the use of inputs given a fixed level of output—i.e., produce the same amount with fewer inputs—and output-oriented models, which seek to maximize the product for a given level of inputs. In this study we used the CCR model and the BCC model, both output-oriented, to compare the scores.

Besides identifying the efficient DMUs, these models provide benchmarking for inefficient DMUs (Soares de Mello et al, 2003). These units can be elaborated through a linear combination of efficient units in relation to the inefficient DMU and not necessarily an existing DMU.

The Free Disposal Hull (FDH) model was proposed by Deprins, Simar, and Tulkens (1984). Different from the CCR and the BCC models, the FDH model does not operate with a convexity assumption. Instead, this model has a discrete nature, i.e., the efficiency reference point for an inefficient DMU is not chosen as a point on a continuous efficiency frontier but rather among the existing DMUs.

An important feature of the FDH model is the concept of dominance. A producer is considered to be dominant over another one if it obtains a higher output with the same input level or with a lower amount of at least one of the inputs. An efficient producer, but not a dominant one, is called “efficient by default” and is recognized as such by the absence of producers in the sample whose indicators are similar to it. The mathematical structure of this model is similar to the BCC model with the introduction of a constraint relaxing the convexity assumption inherent in the DEA model. The structure of the FDH orientation model output is shown below:

$$\square\square\square_{\square,\square,}\square^{+},\square^{-}$$

$$\square.\square \tag{3}$$

$$\square\square_{0} - \square\square + \square^{+} = 0$$

$$\square\square + \square^{-} = \square_{0}$$

$$1\square = 1$$

$$\square \square \{0,1\}^{\square}, \square^{+} \square \square^{\square}_{+}, \square^{-} \square \square^{\square}_{+}, \square \square\square\square\square.$$

where $\square^{+}$ $\square\square\square$ $\square^{-}$and are slack variables. In this case, the efficiency analysis is done relative to the other given DMUs instead of a hypothetical efficiency frontier.

2.2 Integrated Security Areas, Variables, and Data

In Brazil, the police force is divided in two types: military police and civil police. The former works mainly in the prevention of crime. It is on the streets, close to the people in the cities. The latter works mainly with the repression of crime. It is in the civil police stations and investigates crimes after they have happened. Although they have different attributions, both work together and depend on each other. They are both subordinated to the Social Defense Department of Pernambuco.

The military police force is composed of 27 battalions, 12 independent companies, and 1 radio patrol. The civil police force is composed of 217 police stations. These are arranged in 26 integrated security areas (ISA) throughout the state, according to table 1:

Table 1: Integrated Security Area (ISA)

Integrated Security Area (ISA)	*Region*
ISA 1	Santo Amaro
ISA 2	Espinheiro
ISA 3	Boa Viagem
ISA 4	Várzea
ISA 5	Apipucos
ISA 6	Jaboatão dos Guararapes
ISA 7	Olinda
ISA 8	Paulista
ISA 9	São Lourenço
ISA 10	Cabo de Santo Agostinho
ISA 11	Nazaré da Mata
ISA 12	Vitória de Santo Antão
ISA 13	Palmares
ISA 14	Caruaru
ISA 15	Belo Jardim

ISA 16	Limoeiro
ISA 17	Santa Cruz do Capibaribe
ISA 18	Garanhuns
ISA 19	Arcoverde
ISA 20	Afogados da Ingazeira
ISA 21	Serra Talhada
ISA 22	Floresta
ISA 23	Salgueiro
ISA 24	Ouricuri
ISA 25	Cabrobó
ISA 26	Petrolina

These areas form clusters subordinated to metropolitan direction (MD), which are composed of police stations from the principal city and metropolitan region; clusters subordinated to direction of the hinterland 1 (DINTER 1) are composed of police stations from wild and the forest area regions; clusters subordinated to direction of the hinterland 2 (DINTER 2) are composed of police stations of Pernambuco’s countryside region. Police stations specialized in specific crimes are also part of the structure.

In this work, the integrated security areas were used as decision-making units since, currently, they are compared on a monthly basis in terms of the variables that were chosen by managers to be monitored and, because of this, these are the outputs of the proposed model. The description of the inputs and outputs are in the following table 2.

Table 2: Variables of the DEA model

Variable	Description
Civil police employees and military police employees (I)	Sum of the amounts of delegates, officers, and clerks of civil police and soldiers and other patents of military police in an ISA
Weapons seized (O)	Amount of weapons seized by an ISA in 2013
Crack seized (O)	Amount of converted drug seized by an ISA in 2013
Offenders seized (O)	Amount of offenders seized in 2013
Inverse of the ILCV rate (O)	Inverse of the ILVC rate s proxy to the effectiveness of an ISA

I–Input; O–Output.

It is important to note that ILCV rate is a not desired result in the studied production system, that is, it needs to be minimized to benefit the DMU. In models of data envelopment analysis, this variable is known as undesirable output. Defective parts rates, the emission of toxic gases into the environment, crime rate, among others, are examples of undesirable outputs. In general, there are four ways to use these variables in the DEA modeling.

The first was developed by Golany (1989) and means to use the inverse of undesirable variable and thus turn it into desirable ($\square(\square_{\square}^{\square}) = \frac{1}{\square_{\square}^{\square}}$ where, $\square_{\square}^{\square}$ is an element of matrix $\square$ of undesirable outputs $\square$ of the DMUs $\square$). Lovell *et all* (1995) used this technique, known as multiplicative inverse, to model carbon and nitrogen emissions in the environment.

The second was developed by Koopmans (1951) and means to treat the undesirable output as input from an additive inverse transformation $\square(\square) = -\square$. Rheinhard *et al* (1999) used this method to model nitrogen emissions into the environment.

The third is to transfer the values, i.e., add the additive inverse transformation of the undesired output a positive scalar large enough so that the resulting values are positive for each DMU j ($f(y_j^b) = -y_j^b + \beta_j$).

In this paper, we use the first technique presented, as well as the work of de Scalco *et al* (2012).

3. Results and discussion

In this section we introduce a comparative analysis of the efficiency scores in the CCR model, BCC model, and FDH model and present the scale efficiency of the production units, which is used to determine how close an evaluated DMU is, as compared to the most productive scale size. Table 3 indicates the descriptive statistics of the variables used as input and output.

Table 3: Descriptive statistics of the variables used

Models	*Minimum*	*Mean*	*Maximum*	*Std. Dev.*
Total employees	356	629.04	1022	187.53
Weapons seized	65	247.62	506	107.98
Crack seized	186.08	13259.09	147948.3	29802.76
Offenders seized	271	720.65	1378	281.52
Inverse of the ILCV rate	0.01	0.03	0.1	0.01

Note: The variable crack seized was measured in grams.

3.1 Analysis of Efficiency

In this subsection we present the efficiency analysis of all DMUs. Table 4 demonstrates the scores measured in three models and the efficiency scale and table 5 indicated the descriptive statistics of the efficiency scores in each model.

Table 4: Efficiency scores in CCR model, BCC model, and FDH model

DMU	*Efficiency CCR*	*Efficiency BCC*	*Efficiency Scale*	*Efficiency FDH*
ISA 1	0.86	0.87	0.99	0.92
ISA 2	0.69	0.87	0.79	1.00
ISA 3	0.66	0.85	0.78	1.00
ISA 4	0.91	0.94	0.97	1,00
ISA 5	0.64	0.78	0.82	0.98
ISA 6	0.71	0.76	0.93	1.00
ISA 7	1	1	1	1.00
ISA 8	1	1	1	1.00
ISA 9	0.75	0.77	0.97	0.93
ISA 10	0.51	0.5	1	0.80
ISA 11	1	1	1	1.00
ISA 12	0.91	0.93	0.98	1.00
ISA 13	0.69	0.69	1	0.94
ISA 14	0.89	1	0.89	1.00
ISA 15	0.88	0.96	0.92	1.00
ISA 16	0.74	0.77	0.96	1.00
ISA 17	0.88	0.94	0.94	1.00
ISA 18	0.88	0.91	0.97	1.00
ISA 19	1	1	1	1.00
ISA 20	1	1	1	1.00
ISA 21	0.72	0.77	0.94	1.00

ISA 22	1	1	1	1.00
ISA 23	0.75	0.76	0.99	1.00
ISA 24	1	1	1	1.00
ISA 25	0.95	1	0.95	1.00
ISA 26	0.89	0.92	0.97	1.00

Table 5: Descriptive statistics of the efficiency scores in each model

Descriptive Statistic	*CCR*	*BCC*	*FDH*
Minimum	0.51	0.50	0.79
Mean	0.84	0.88	0.98
Maximum	1.00	1.00	1.00

The mean scores in the CCR and BCC models were similar (0.84 and 0.88) and lower than the average in the FDH model, which was 0.98. In the CCR model, we obtained 7 efficient units: ISA 7, ISA 8, ISA 11, ISA 19, ISA 20, ISA 22, and ISA 24. All these efficient units also obtained scores equal to 1 in the BCC model. Besides them, ISA 14 and ISA 25 were efficient too, based on BCC model. The FDH model revealed 21 efficient security areas, 16 efficient by default and 5 dominating other areas. These last 5 were: ISA 7 dominating ISA 1, ISA 19 dominating ISA 13, ISA 24 dominating ISA 10, ISA 25 dominating ISA 9, and ISA 26 dominating ISA 5.

The results demonstrate that 34% of the units were efficient in the BCC model. When we considered constant returns to scale, we got 26%. The highest percentage of efficient units, 80%, was obtained in the FDH model, which was expected since this model is less restrictive. The average efficiency in this model was also higher: 98%.

The amount of police seems to be a bottleneck; there is no slack in the variable amount of police in both CCR and BCC models. In the CCR model there is no slack in this variable at all. In the BCC model there are slacks in 3 areas: ISA 2 (10%), ISA 3 (11%), and ISA 5 (5%). The manager could use these slacks, for example, to increase the quantity of seized arms or, in the case of ISA 2, the amount of converted crack seized.

On the side of the outputs, in the CCR model, it was observed that about 53% of the ISAs studied have the potential to increase the amount of seized weapons; 30% of the ISAs studied have the potential to increase the amount of crack cocaine seized, and only ISA 21 has the potential to increase the amount of offenders seized. In the BCC model, it was observed that about 38% of the ISAs studied have the potential to increase the amount of seized weapons, 42% of the ISAs studied have the potential to increase the amount of crack cocaine seized, and only ISA 21 has the potential to increase the amount of offenders seized.

Table 6 presents the benchmarks for both models. In the BCC model, in the set of ISAs considered efficient, ISA 20 was the area used as a reference to create benchmarking. In the CCR model, ISA 19 was the area used as reference. It is interesting to note that both DMUs are located in Pernambuco’s countryside. The dominant areas in the FDH model were also used as benchmarks in the BCC model, except for ISA 26. Regarding the CCR model, this condition was verified only for ISA 19.

Table 6: Benchmarks

Integrated Security Area	*Benchmarks–BCC*	*Benchmarks–CCR*
ISA 7	4 times	7 times
ISA 8	4 times	1 time
ISA 11	9 times	7 times
ISA 14	7 times	-
ISA 19	6 times	14 times
ISA 20	11 times	7 times
ISA 22	2 times	1 time

ISA 24	3 times	7 times
ISA 25	2 times	-

The ISA 7, ISA 8, ISA 10, ISA 11, ISA 13, ISA 19, ISA 20, ISA 22, and ISA 24 presented scale efficiency equal to 1; that is, these units were operating at optimal scale. The proportion of scale-inefficient ISAs was around 65%. Interestingly, ISA 10 and ISA 13 were areas considered inefficient in both models.

Furthermore, we found that, although the proportion of inefficient areas was high in both the CCR and BCC models (73% and 69%, respectively), the mean efficiency values were close to 0.9. This indicated that the government of Pernambuco had a good opportunity to make these areas operate more efficiently.

As we mentioned, in order to maximize the output, in this paper we adopted the model-oriented product. Furthermore, given the wide variation in the sizes and characteristics of each area analyzed, we used the scores from the DEA model with variable returns to scale in cluster analysis.

4. Conclusions

The objective was to obtain efficiency measures for 26 integrated security areas of Pernambuco and analyze the scores obtained in order to generate management information. For this, we used DEA-BCC, DEA-CCR, and FDH models that were output oriented to obtain scores, compare, and calculate the scale efficiency.

The results demonstrate that 34% of the units were efficient in the BCC model. When we considered constant returns to scale, we got 26%. The highest percentage of efficient units, 80%, was obtained in the FDH model, which was expected since this model is less restrictive. The average efficiency in this model was also higher at 98%.

Analyzing the scale efficiency, we found that 9 areas had scale efficiency equal to 1, i.e., they were operating at optimal scale. The proportion of scale-inefficient ISAs was around 65%. ISA 10 and ISA 13, which were areas considered inefficient in both models, operated at optimal scale.

Furthermore, we found that, although the proportion of inefficient areas was high in both the CCR and BCC models (73% and 69%, respectively), the mean efficiency values were close to 0.9. This indicated that the government of Pernambuco has a good opportunity to make these areas operate more efficiently.

Most of the efficient units are located in Pernambuco’s countryside. In the BCC model, ISA 20, the municipality of this region, was the efficient area that became the benchmark for the inefficient areas.

By analyzing the distribution of efficient areas in the territory, we found that about 60% of efficient areas are located in Pernambuco’s countryside. This result suggests that socioeconomic characteristics may influence the efficiency of these units. An analysis of this hypothesis is suggested for future work.

Finally, this empirical study has limitations regarding the model and the data. Firstly, DEA assumes that all DMUs are homogenous in their environments; it is a deterministic approach that does not allow errors in measurements. Secondly, we had some doubts about the quality of the data. Despite these limitations, the research provides an alternative to measure police efficiency in terms of various inputs and outputs. Furthermore, it allows locating the bottlenecks and creating benchmarks from the efficient units, i.e., it is possible to analyze what can be improved to achieve maximum efficiency and how the efficient units are distributed throughout the state.

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