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Artigos

Measuring the technical and scale efficiency of Rio de Janeiro samba schools: a DEA approach

Mensuração da eficiência técnica e de escala das escolas de samba do Rio de Janeiro: uma abordagem DEA

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Abstract
This article aims to measure the technical and scale efficiency of the 12 samba schools that paraded in the Rio de Janeiro Carnival special group in 2017. For this, it was used an output oriented model through the Data Envelopment Analysis technique. The component number of each school was adopted as an input data and, by the oder hand, as the choiced output, three of the nine judged grades questions throughout the parade, were are selected through the Principal Component Analysis method. The results show that only Mocidade showed technical and scale efficiency, so, it is a benchmark for the other samba schools. It was also observed that the global technical inefficiency average, evaluated at 8%, was strongly influenced by the low scale efficiency of the samba schools, which, in the majority, had decreasing scale returns. In light of this, alternatives are presented to increase the samba schools efficiency.

Keywords: Measurement Efficiency; Data Envelopment Analysis; Samba Schools.

Resumo
Este artigo tem como objetivo medir a eficiência técnica e de escala das 12 escolas de samba que desfilaram no grupo especial do Carnaval do Rio de Janeiro em 2017. Para isso, utilizou-se um modelo orientado a outputs através da técnica Data Envelopment Analysis. O número de componentes de cada escola foi adotado como o dado de entrada e, por outro lado, como a saída escolhida, três dos nove quesitos de avaliação ao longo do desfile foram selecionadas através do método de Análise de Componentes Principais. Os resultados mostram que apenas a Mocidade demonstrou eficiência técnica e de escala, sendo assim, uma referência para as outras escolas de samba. Observou-se também que a média de ineficiência técnica global, avaliada em 8%, foi fortemente influenciada pela baixa eficiência de escala das escolas de samba, que, em sua maioria, apresentaram retornos de escala decrescentes. Diante disso, alternativas são apresentadas para aumentar a eficiência das escolas de samba.

Palavras-chave: Eficiência de medição; Análise de envoltório de dados; Escolas de samba.

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1 Introduction

The Rio de Janeiro Carnival, a main festival in Brazil, has international repercussions, attracts thousands of tourists and is an important jobs and income source (Costa, Silva & Ramalho, 2010). The "folia climax" is the special group samba schools parade, considered the largest outdoor audiovisual event in the world (Pompeu & Perez, 2008). The growing competition for the Carnival champion title has made samba schools adopt modern administrative practices (Rego & Lopes, 2008; Tureta & Araújo, 2013), so that, the efficiency is one of the most desired attributes (Lopes, Malaia & Vinhais, 2009).

Recent papers utilized the Data Envelopment Analysis (DEA) technique to mensurate the banking efficiency (Paradi & Zhu, 2013), European soccer teams (Pyatunin et al., 2016), NBA basketballs teams (Chen, Gong & Li, 2017) and cinematographic enterprises (Hababou, Amrouche & Jedidi, 2016), the above mentionated organizations, as the samba schools ones, operates in markets where the competition level is high. Despite of the aforementioned information, there are no papers in the scientific literature that discuss the use of the DEA technique to evaluate the samba schools efficiency.

In order to fill this gap, the paper objective is to measure, through a DEA model, the samba schools efficiency that paraded in the special group of the Rio Carnival in the year of 2017. Specifically, it is intended to calculate the technical and scale efficiencies and identify the types of scale returns that each school had operated. In this way, alternatives can be pointed out aiming to contribute and increasing the samba schools efficiency.

In addition to this introduction, this article contains four more sessions. The next one emphasizes the DEA technique as a measurement tool of technical and scale efficiency. In the third one, the research methods are shown and in the fourth the results founded are discussed. Finally, the conclusions were presented.

2 Measuring the technical and scale efficiency through the DEA model

The Data Envelopment Analysis it is considered a non parametric measuring efficiency technique, especially widespread by the Charnes, Cooper & Rhodes (1978) and Banker, Charnes & Cooper (1984) seminal studies. It is admitted that N Decision Making Units (DMU) uses a common technology (ψ) to transform an input vector $x_n = (x_{n1},\dots,x_{np}) \in \Re^p_+$ into an output vector $y_n = (y_{n1},\dots,y_{np}) \in \Re^q_+$. Therefore, it is possible do define a set of production possibilities, formed by the feasible planes (x, y), such that: $\wp = \{(x, y) \in \Re^{p+q}_+ | x\, can\ produces\ y\}$.

Though ψ it is not observable, the DEA technique, by the use of linear programming, calculates the $\wp$ estimative, given by (1), when setting the smallest space $\Re^p_+ x\, \Re^q_+$ subset that contains the pair (x_n, y_n) and satisfies: the free inputs and outputs discard; the convexity production possibilities set as well as its scale returns, that can be considered constants (CRS) or variables (VRS) (Bogetoft & Otto, 2010):

$$\hat{\wp}(\gamma)=\left\{(x,y)\in\Re_{+}^{p+q}\,\middle|\,\exists n\in\Lambda^{N}(\gamma):x\geq\sum_{n=1}^{N}\lambda_{n}x_{n},\,y\leq\sum_{n=1}^{N}\lambda_{n}y_{n}\right\} \quad (1)$$

where:

$$\Lambda^{N}(CRS)=\left\{\lambda\in\Re_{+}^{N}\,\middle|\,\sum_{n=1}^{N}\lambda_{n}\ \ free\right\} \quad (2)$$

$$\Lambda^{N}(VRS)=\left\{\lambda\in\Re_{+}^{N}\,\middle|\,\sum_{n=1}^{N}\lambda_{n}=1\right\} \quad (3)$$

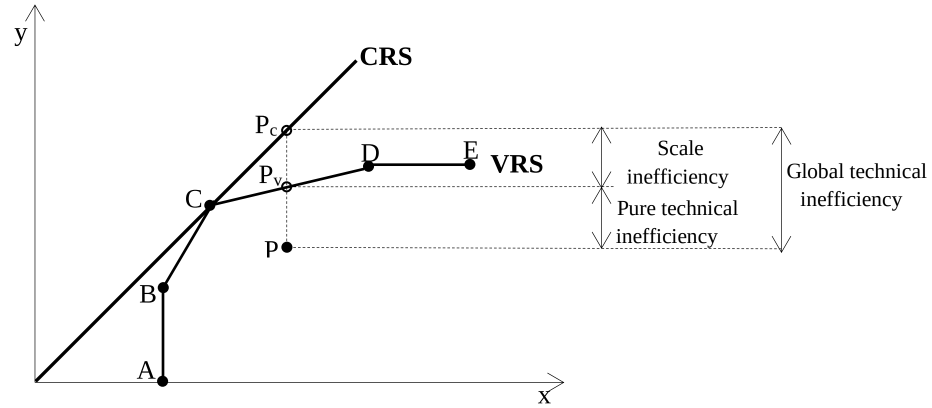
The DEA models can be oriented by *inputs,* when the purpose is reducing *inputs*, keeping the *outputs* constants, or oriented by *outputs*, when the goal is to increasing *outputs*, fixing the *inputs*. The second one model will be adopted in the present paper and the efficiency score, DMU$_0$, $0\leq\hat{\delta}_0\leq 1$, is giving by:

$$\begin{aligned} &\hat{\delta}_0=\max_{\delta,\lambda_1,\ldots,\lambda_N}\delta \\ &x_{0i}\geq\sum_{n=1}^{N}\lambda_n x_{ni},\ i=1,\ldots,p \\ &\delta y_{0j}\geq\sum_{n=1}^{N}\lambda_n y_{nj},\ i=1,\ldots,q \\ &\lambda\in\Lambda^{N}(\gamma) \end{aligned} \quad (4)$$

The DMU$_0$ efficiency score obtained under the assumption of constant scale returns is designed by the global technical efficiency while the another one, obtained under the assumption of variable scale returns it is characterized by the technical efficiency pure. The ratio between these two measures provides the scale efficiency (Ferreira & Gomes, 2009). In other words, the global technical inefficiency is composed by the pure technical inefficiency and the scale technical inefficiency.

The Figure 1 illustrates geometrically the presented concepts. For this, it is considered an input and an output and a model based on an outputs orientation. In this way, the efficient limits calculated by the DEA model are presented under the constant return to scale (CRS) assumptions, to which DMU C belongs and the variable scale returns (VRS), consisting of the DMUs A, B, C, D and E. The last one contains a part with non-decreasing scale returns (A to C) and one with non-increasing scale returns (C to E). Realize that the DMU P does not belong to those borders, therefore, it is inefficient. Under the assumption of constant scale returns, the global technical inefficiency of P is characterized by the distance PP$_C$. By the oder hand, under the assumption of variable returns to scale, the pure technical inefficiency of P is designed by the distance PP_V. The difference between these two techniques, given by the distance P_VP_C, it is called by the scale inefficiency of P.

Figure 1 - Technical efficiency and scale efficiency



Source: Ferreira & Gomes (2009, p. 192, adapted).

If the scale efficiency it is equal to one, then the DMU will be operating with constant returns to scale, but if it is smaller than one, there may be increasing or decreasing scale returns. That is, the scale efficiency does not identify the type of scale return that a DMU is operating (Banker, Charnes & Cooper, 1984). To do so, for all optimal solutions (4), one of them must check the following conditions (Banker et al., 2004):

i. The scale returns will be increasing if, and only if, $\sum_{n=1}^{N} \lambda_n < 1$;

ii. The scale returns will be decreasing if, and only if, $\sum_{n=1}^{N} \lambda_n > 1$;

iii. The scale returns will be constantly if, and only if, $\sum_{n=1}^{N} \lambda_n = 1$.

3 Methods

The present research adopted a cross section approach when analyzing the Carnival data of Rio de Janeiro for the year 2017, which were collected on the site of the Independent League of Samba Schools (LIESA). The selected DMUs were the 12 samba schools that paraded the aforementioned year in the special group: Paraíso do Tuiuti, Grande Rio, Imperatriz, Vila-Isabel, Salgueiro, Beija-Flor, União da Ilha, São Clemente, Mocidade, Unidos da Tijuca, Portela e Mangueira.

The input utilized was the components number (COMP) that each school decided to led to the parade, which, as a rule, should be between 2,500 and 3,500 (LIESA, 2017b). This indicator it is important because it reflects the amount of labor employed, an obvious input from any production process (Cook, Tone & Zhu, 2014).

Outputs are called process results (Charnes et al., 2013). Thus, it is considered as outputs the sums of the valid notes obtained by the samba schools in each one of the questions judged during the parade (Chart 1). In 2017 nine items were scored, each one by four jurors, totaling 36 judgments. Each jury awarded a score ranging from nine to ten points, which could be fractioned in tenths. In the result calculation, for each item, only the three highest grades were accepted as valid, that is, the lowest grade was discarded (LIESA, 2017b). Mocidade and Portela, the champion ones, obtained exactly 269.9 points in the sum of the valid scores, according to all the judgment criteria.

Chart 1 - Criteria and Judged Factors

Criteria	Judged Factors
Battery (BAT)	Maintenance and support of the Battery cadence in line with the Samba-Plot, conjugation of the sounds emitted by the instruments as well as Battery creativity and versatility.
Samba Plot (SP)	Samba-Plot letter and melody, respecting the poetic license.
Harmony (HAR)	Connection between rhythm and singing.
Evolution (EV)	Dance progression according to the samba rhythm that is being executed and with the cadence maintained by the battery.
Plot (PLT)	Creation and artistic presentation of a theme or concept.
Allegories and Adornments (A&A)	Any scenographic element that is on wheels (allegories) or not (adornments).
Fantasies (FAN)	Fantasies presented by the samba school, except those that are on the allegories, the couples fantasies of “Mestre-Sala” and “Porta-Bandeira” and the Front Committee.
Front Committee (FC)	Costume suitability of the Front Committee, ability to positively impact the audience, at the samba school time of presentation, coordination, timing and creativity of its exhibit.
“Mestre-Sala” and “Porta-Bandeira” (MS)	The couple's costume, which should be suitable for dancing; impression caused by its shapes and finishes; beauty as well as good taste and harmony.

Source: LIESA (2017a)

Therefore, for each of the 12 DMUs, an input and nine outputs were considered, whose statistics are shown in Table 1. However, it is recommended that the number of DMUs it is equal to at least three times the number of inputs and outputs (Banker et al., 1989), since the large number of inputs and outputs compared to the DMUs number, decreases the DEA discriminatory power (Cook, Tone & Zhu, 2014). Since it was not possible to increase the DMUs number, once that only 12 samba schools belong to the Rio de Janeiro Carnival special group, and in order to meet that recommendation, it was decided to reduce the number of outputs to three.

Table 1 - Variables descriptive statistics

Variable	Type	Min	Max	Mean	Standard deviation
COMP	*Input*	3000	3500	3259,58	203,07
BAT		29,6	30,0	29,89	0,16
SP		29,5	30,0	29,83	0,19
HAR		29,1	30,0	29,79	0,27
EV		29,2	30,0	29,76	0,29
PLT	*Output*	29,2	30,0	29,79	0,24
A&A		29,5	30,0	29,82	0,22
FAN		29,3	30,0	29,85	0,23
FC		29,3	30,0	29,77	0,23
MS		29,4	30,0	29,87	0,18

In order to select the three most relevant outputs it was used the Principal Component Analysis (PCA) technique, which aims to explain a random vector: variance and covariance structure, composed of random p-variables, by constructing some linear combinations of k ($k < p$) original variables - the main components - not correlated with each other (Hongyu, Sandanielo & Oliveira Júnior, 2016). Thus, from the original variables set, initially correlated, it is possible obtain a substantially smaller set of uncorrelated variables that contain most of the information.

Table 2 presents the applying PCA results to the covariance matrix of the valid scores questions sum. The total variance, given by the eigenvectors sum of the covariance matrix, it is equals to 9.001. The first major component (PC1), which contains the most relevant information from the original data, explains 62.72% of the total variance.

Table 2 - Principal component analysis

Component	Eigenvalues	Explained variance (%)	Cumulative explained variance (%)
PC1	5,645	62,72	67,72
PC2	1,313	14,59	77,30
PC3	0,775	8,61	85,91
PC4	0,561	6,23	92,15
PC5	0,485	5,39	97,53
PC6	0,140	1,56	99,09
PC7	0,055	0,61	99,70
PC8	0,024	0,27	99,97
PC9	0,003	0,03	100,00
Total	**9,001**	**100,00**	-

The PC1, given by (5), can be understood as a vector of items weights linked to the samba schools overall performance. Because they have the highest coefficients, the valid scores sum of the EV, HAR and A&A are the three most important variables (Mingoti, 2004) of PC1. The eigenvectors, which are composed of coefficients that correspond to each variable, are used to calculate the scores of the major components. The coefficients indicate the relative weight of each variable in the component (Mingoti, 2004). Therefore, these were considered as outputs.

$$PC1 = 0{,}917EV + 0{,}899HAR + 0{,}874A\&A + 0{,}863MS + 0{,}853FC + 0{,}742PLT + 0{,}735\,SP + 0{,}725FAN + \ O,346BAT \quad (5)$$

In the data analysis, output-oriented DEA models were adopted. Initially, under the assumption of constant returns to scale, the global technical efficiency scores were calculated. With this assumption relaxed, the pure technical efficiency scores were computed. Of the reason between these measures, the scale efficiency scale was ascertained. Finally, the returns to scale were classified as constant, increasing or decreasing.

4 Results and Discussion

Table 3 presents the efficiency scores and scale returns to the 12 special group samba schools of Rio de Janeiro Carnival in 2017. It is possible to perceive that, under the assumption of constant scale returns, only the Mocidade obtained the maximum global technical efficiency. In this criterion the average level of inefficiency was 0.08 (1-0,920), which means that schools could, on average, increase valid grades in Evolution, Harmony and Allegories and Adornments by up to 8%, without increasing the number of components.

The global technical inefficiency can be caused by pure technical inefficiency and / or scale inefficiency. In order to evaluate the scale influence, the assumption of constant returns was relaxed. Once this was done, pure technical efficiency scores were obtained, with a mean of 0.996. Therefore, it can be stated that, on average, the overall technical inefficiency of 8% is due less to the pure technical inefficiency, which was 0.4% (1 - 0.996), and more to the scale inefficiency, whose average was 7.6% (1-0.924). It is also verified that in addition to Mocidade, the Grande Rio, Beija-Flor, Portela, Salgueiro and Mangueira schools presented pure technical efficiency.

It is still shown in Table 3 that Mocidade, Imperatriz and São Clemente had constant scale returns, which indicates that these schools operated at an optimal scale. However, only the first one was technically efficient; the other two, to be efficient must, using the same components number, increase the valid notes in the criteria: Evolution, Harmony and Allegories & Adornments. The other schools presented decreasing scale returns, that is, they operated above the optimal scale. In the case of Grande Rio, Beija-Flor, Portela, Salgueiro and Mangueira, which presented pure technical efficiency, the current valid notes should be maintained in the requirements of Evolution, Harmony and Allegories & Adornments and reduced the number of components. In order to correct the problems of the Paraíso do Tuiuti, Vila Isabel, União da Ilha and Unidos da Tijuca schools, which operated above the optimal scale and were still technically inefficient, respectively, the components number should be reduced and the grades, should be increased in the following criteria: Evolution, Harmony and Allegories & Adornments. In order to become efficient, inefficient schools should target the input and outputs of the Mocidade, the efficiency benchmark school: 3,000 components and 30.0 points sum of valid grades in the Evolution, Harmony and Allegories & Adornments requirements.

Table 3 - Escores de eficiência e retornos de escala das escolas de samba do Rio de Janeiro

DMU	Samba school	Technical Efficiency		Scale Efficiency	School Returns
		Global	Pure		
1	Mocidade	1,000	1,000	1,000	Constant
2	Imperatriz	0,993	0,993	1,000	Constant
3	São Clemente	0,993	0,993	1,000	Constant
4	Paraíso do Tuiuti	0,952	0,983	0,968	Decreasing
5	Grande Rio	0,938	1,000	0,938	Decreasing
6	Vila Isabel	0,931	0,993	0,938	Decreasing
7	Beija-flor	0,909	1,000	0,909	Decreasing
8	União da Ilha	0,879	0,997	0,882	Decreasing

9	Portela	0,878	1,000	0,878	Decreasing
10	Salgueiro	0,857	1,000	0,857	Decreasing
11	Mangueira	0,857	1,000	0,857	Decreasing
12	Unidos da Tijuca	0,851	0,993	0,857	Decreasing
Mean		**0,920**	**0,996**	**0,924**	

5 Conclusion

The present research showed that the DEA technique can be useful to measure the technical and scale efficiencies of samba schools. It was verified that only one samba school inserted on the special group of Rio de Janeiro Carnival in 2017, Mocidade, had the global technical efficiency. It was also found that, although Grande Rio, Beija-Flor, Portela, Salgueiro and Mangueira, as well as Mocidade, presented pure technical efficiency, the average global technical inefficiency was 8%.

This result was strongly influenced by the low scale efficiency of the samba schools, which mostly, presented decreasing scale returns, which shows that they operated above the optimal scale. Therefore, in order to become efficient, samba schools must reduce the components number and / or increase its performance in the evaluating criteria, with reference to Mocidade, the samba school benchmark.

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