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OBJECTIVE WEIGHTING AND AGGREGATION METHODS IN COMPOSITE INDICATORS: A COMPARATIVE ANALYSIS OF THE SOCIAL RESPONSIBILITY INDEX IN MINAS GERAIS MUNICIPALITIES

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Abstract. *This study compares alternative methods for constructing composite indicators, focusing on weighting and aggregation. Using the five dimensions of the Social Responsibility Index (SRI) for 853 municipalities in Minas Gerais, Brazil, the CRITIC and Gini weighting methods were combined with the TOPSIS, DP2, and ADRIANA aggregation methods. The comparison is based on score distributions, Spearman correlations, and categorical classifications. Results show that, despite distinct formulations, the methods produce similar distributions and rankings, indicating strong robustness of composite indicators to methodological choices.*

Keywords: *Composite Indicators; Multicriteria Methods; CRITIC; Gini Coefficient; Social Responsibility Index*

1. INTRODUCTION

The evaluation of public sector performance has increasingly turned towards data-driven approaches (Afonso et al., 2005), requiring the processing of multidimensional datasets encompassing health, education, income, environment, governance, among others. In this scenario, composite indicators emerge as a practical tool to synthesize complex information into comparable measures, supporting planning and the formulation of public policies (OECD/EU/EC-JRC, 2008).

The construction of composite indicators is of extreme importance for conducting analyses and defining action plans by the public sector; however, the construction of such indicators can often be challenging regarding the aggregation and weighting used in generating the indices.

Especially in the weighting process, it is common that poorly calibrated weights may not reflect the real importance or dimensionality of the data, compromising the reliability of the index (Greco et al., 2018; Mazziotta and Pareto, 2016).

This article contributes to this gap by comparing weighting methods less commonly used in the literature. The CRITIC and GINI weighting methods, applied in conjunction with three aggregation and ranking methods, TOPSIS, DP2 and ADRIANA, in the construction of the Social Responsibility Index (SRI) for the municipalities of Minas Gerais. The comparison is made based on the distributions of scores, Spearman correlations, and mean rank differences, providing empirical evidence on the robustness and stability of composite indicators against different methodological choices.

2. METHODS

This section presents the methods used in the construction and comparison of composite indicators. Two objective criteria weighting methods, CRITIC and the Gini Coefficient, and three aggregation and alternative ranking methods, TOPSIS, ADRIANA and DP2, are described, allowing the evaluation of the effect of combining different weighting and aggregation forms on the final result.

2.1 CRiteria Importance Through Intercriteria Correlation (CRITIC) Method

The CRITIC method (Diakoulaki et al., 1995) assigns objective weights to criteria by combining their variability, given by the standard deviation σ_j, with their conflict relative to other criteria given by Pearson correlation r_{jk}, so that dimensions with higher dispersion and lower redundancy receive larger weights.

The formulations used in the weight formation involve the calculation of the information transmitted by a criterion $C_j = \sigma_j \cdot \beta_j, \quad \beta_j = \sum_{k=1}^{m}(1 - r_{jk})$

In this study, CRITIC was applied to the five normalized SRI dimensions to obtain a fully data-driven weighting vector, used as input to the three ranking methods described below.

2.2 Gini Coefficient Weighting Method

The Gini weighting method adapts the classical inequality measure, the Gini coefficient, to multicriteria problems, assigning larger weights to dimensions that show greater dispersion (inequality) among municipalities:

The formulation of the Gini Coefficient, applied to each criterion and subsequently normalized for weight generation, is given by $G_j = \frac{\sum_{i=1}^{n}\sum_{h=1}^{n}|x_{ij}-x_{hj}|}{2n^2\bar{x}_j}$, as denoted in the study (Renzi et al., 2026).

It was included as a contrasting logic to CRITIC, rewarding dimensions that most differentiate municipalities, which is particularly relevant for identifying regional disparities in social responsibility.

2.3 Technique for Order Preference by Similarity to an Ideal Solution (TOPSIS)

TOPSIS orders alternatives based on the distance to the positive ideal solution S_i^+ and the negative ideal solution S_i^-, considering the best alternative as the closest to the former and the farthest from the latter (Moghadas et al., 2019; Bhusal et al., 2025). The relative closeness is calculated as: $RC_i = \frac{S_i^-}{S_i^- + S_i^+}$

with municipalities ranked in descending order of RC_i. TOPSIS was applied using the CRITIC, Gini, and equal-weight vectors, allowing the same distance-based ranking logic to be tested under three different weighting schemes.

2.4 Interactive Relative Decision Analysis of Acquisition and Non-Acquisition (ADRIANA) Method

ADRIANA (Hein, 2020) decomposes each municipality's performance into an acquisition utility Av_i (relative advantage over other municipalities) and a non-acquisition utility NAv_i (deviation from the mean), combined into the Thaler value: $VTH_i = \lambda \cdot Av_i + (1 - \lambda) \cdot NAv_i$. This combination of concepts incorporates behavioral logic into multicriteria decision-making.

Following the method's original formulation, $\lambda = 0.5$ was adopted. ADRIANA was applied with the same three weighting schemes, offering a behaviorally motivated alternative to the distance-based logic of the other aggregation methods.

2.5 Distance P2 (DP2) Method

The DP2 method, proposed by Pena Trapero (Trapero, 2009), constructs synthetic indicators by measuring the distance of each alternative to an undesirable reference situation (the worst observed value in each criterion), eliminating information redundancy through a correlation factor.

After aligning all criteria in the same direction and calculating the distance matrix D_{ij} relative to the reference value, the index is defined by: $DP2_i = \sum_{j=1}^{m} \frac{D_{ij}}{\sigma_j} \left(1 - R^2_{j,j-1,\ldots,1}\right)$, where R^2 is the coefficient of determination of the regression of the criterion in the established entry order. Since the DP2 value depends on this order, an iterative process, based on the correlation of each criterion with a provisional index, determines the optimal sequence until convergence (Montero et al., 2010).

The implementation carried out for this work includes a modification to the original method to allow the use of externally generated weights, in order to enable an equivalent comparison with the other methods.

2.6 Methodological Workflow

The overall workflow adopted in this study follows the steps: (i) min-max normalization of the dimensions to the [0,1] interval; (ii) estimation of two weighting vectors from the normalized matrix, using CRITIC and Gini; (iii) application of TOPSIS, DP2, and ADRIANA to the normalized matrix under each weighting vector, as well as under equal weights, yielding ten method-weighting combinations, including DP2 without external weights; (iv) comparison of the combinations through score distributions, Spearman correlations, and categorical classification of municipalities.

3. DATA AND CONSTRUCTION OF THE INDICES

As an empirical application, data from the 853 municipalities of Minas Gerais were used, referring to the dimensions of the Minas Gerais Social Responsibility Index (IMRS), prepared by the João Pinheiro Foundation. Five dimensions were considered: Health, Education, Public Safety, Social Vulnerability, and Sanitation and Environment, each synthesizing specific social responsibility indicators in the municipalities.

Health captures coverage and quality of health services, including primary care and infant and preventable mortality; Education reflects access, flow, and quality of the municipal school system; Public Security measures crimes against life and property; Social Vulnerability captures poverty, exclusion, and socioeconomic fragility; and Sanitation and Environment covers water supply, sewage, waste collection, and environmental sustainability.

The five dimension scores were normalized to the [0,1] interval using min-max normalization, which preserves the relative position of each municipality while placing all dimensions on a common scale. This normalized matrix constitutes the input for the CRITIC and Gini weighting procedures 2.1, 2.2 and for the three ranking methods 2.3, 2.4, 2.5, which were also computed under equal weights as a baseline for comparison.

4. RESULTS

In this study, dimension weights were estimated using the CRITIC and Gini methods, allowing an objective and data-driven assessment of the relative importance of each dimension. These weightings were then combined with the TOPSIS, DP2 and ADRIANA methods to construct the final municipal rankings, enabling comparison between the different methodological combinations.

Figure 1 displays the standardized score distributions obtained for each method-weighting combination. Although the methods differ considerably in their mathematical formulation and original scale, the resulting density curves are remarkably close in shape. This pattern suggests that neither the aggregation procedure nor the weighting scheme systematically shifts the overall level of the scores, and that no method tends to produce a more favorable or a more unfavorable assessment of the municipalities as a whole.

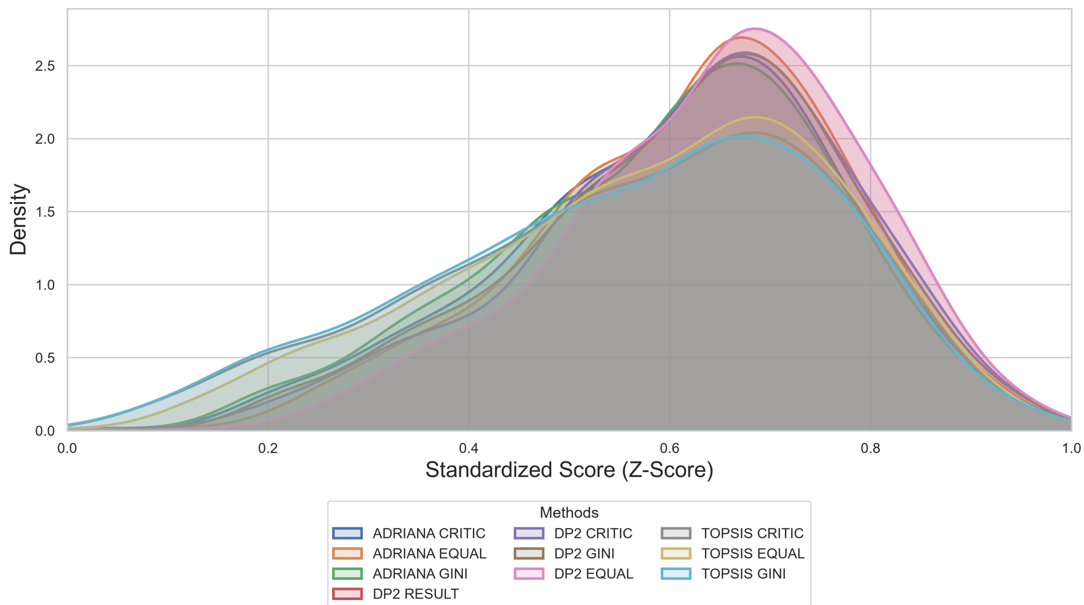

Figure 1: Density distribution of scores by method.

A complementary view of this convergence is provided by the Spearman correlation matrix in Figure 2. The coefficients obtained for all method pairs are consistently high, pointing to a strong agreement in how municipalities are ordered regardless of the approach used. In practical terms, this means that municipalities placed at the top or at the bottom of the distribution tend to occupy comparable relative positions across the different rankings, reinforcing the idea that the methodological choice has limited influence over the overall ordering.

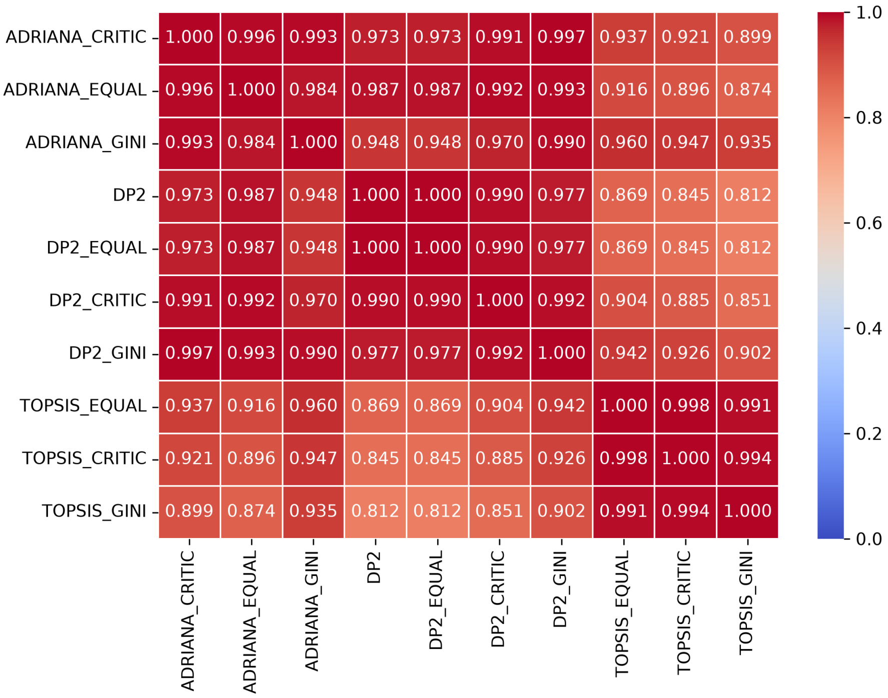

Figure 2: Heatmap of municipal rankings across different methods.

Table 1 complements the previous analyses by showing how the 853 municipalities are distributed across five SRI categories, from Very Low to Very High, under each method-weighting combination. The categorical distributions are broadly similar. The bulk of municipalities consistently falls into the intermediate and upper-intermediate classes, while the proportion of municipalities in the extreme categories remains comparatively stable across methods. Taken together, these results indicate that the qualitative reading of municipal social responsibility levels is largely unaffected by the specific combination of normalization, weighting, and aggregation procedure adopted.

Table 1: Classification of municipalities by SRI category

Category	ADR–C	ADR–G	ADR–EQ	DP2	DP2–C	DP2–G	DP2–EQ	TOP–C	TOP–G	TOP–EQ
Very Low	9	14	5	2	9	7	2	43	42	26
Low	98	108	81	63	88	90	63	136	141	131
Medium	261	261	254	241	245	251	241	259	253	261
High	396	388	415	420	404	401	420	328	336	348
Very High	89	82	98	127	107	104	127	87	81	87

ADR–C = ADRIANA CRITIC; ADR–G = ADRIANA GINI; ADR–EQ = ADRIANA EQUAL WEIGHTS; DP2 = DP2; DP2–C = DP2 CRITIC; DP2–G = DP2 GINI; DP2–EQ = DP2 EQUAL WEIGHTS; TOP–C = TOPSIS CRITIC; TOP–G = TOPSIS GINI; TOP–EQ = TOPSIS EQUAL WEIGHTS.

Overall, the evidence gathered from the density curves, the rank correlation structure, and the categorical classification converges toward the same conclusion: the methodological choices examined here do not materially change the substantive assessment of social responsibility across Minas Gerais municipalities. This consistency lends empirical support to the robustness of the composite indicators considered, reinforcing their suitability as tools for public policy evaluation and decision-making.

5. CONCLUSIONS

This study set out to compare alternative approaches to constructing composite indicators, drawing on data from the 853 municipalities of Minas Gerais and the five dimensions that compose the Social Responsibility Index (SRI). TOPSIS, DP2, and ADRIANA were assessed both in their original, equally weighted formulations and in versions incorporating CRITIC and Gini weights.

The methods converged toward similar score distributions, high Spearman rank correlations, and closely aligned categorical classifications, with only moderate variation in ranking positions. Such convergence points to a composite indicator that is largely robust to the normalization, weighting, and aggregation choices considered in this study.

More broadly, these findings offer empirical support for the stability of unconventional composite-indicator methods, underscoring their value for condensing multidimensional socioeconomic information and for informing evidence-based public policy decisions.

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