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NEW ABC MULTICRITERIA CLASSIFICATION WITH ANALYTICAL HIERARCHY PROCESS: HOW TO ATTRIBUTE WEIGHTS AND FORCE CONSISTENCY OF PAIRWISE COMPARISONS MATRIX

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Resumo: *Multicriteria classification is usually a crucial step in the decision-making in the manufacturing and purchasing management process. For such classification, the attribution of weights to the criteria, as well as the attribution of weights to the products according to each criterion, strongly influences the coherence of the categorization. Saaty's Analytic Hierarchy Process (AHP) is an eminent method for assigning weights to multiple criteria. AHP's logic is not complicated at all. However, since criteria's pairwise comparison matrices are usually generated manually and based only on some employee know-how, there is high complexity in elaborating a consistent pairwise matrix, especially when comparing several criteria. This paper presents a constructive algorithm that can adjust inconsistent matrices, forcing such matrices to have a better consistency rate and a new procedure and equation for ABC multicriteria classification. We tested the proposed solutions by applying the AHP method for ABC multicriteria classification to companies in three sectors. As a result, we observed that the algorithm for forcing consistency adjusts the pairwise matrices in just a few seconds, avoiding the manual work of several hours and that the new solution method developed for multicriteria classification provided consistent results according to the analysis of company managers, showing to be essential resources for applying the AHP and ABC multicriteria classification methods.*

Palavras-chave: *ABC multicriteria classification, analytic hierarchy process, consistency rate, constructive algorithm, COPSolver library*

1. INTRODUCTION

"Manufacturing decisions can be classified into three categories: strategic, tactical and operational ... Operational decisions pertaining to issues such as order processing, detailed production scheduling, follow up, maintenance routines, and inventory control rules, drive the day to day activities" (Singhal *et al.*, 2013). Manufacturing decisions are closely related to sales decisions. "In today's competitive market the diversity in customer's need have resulted in a high level of variability in the products which have to be manufactured" (Ebrahimi *et al.*, 2014) or acquired from other companies. Such diversity brings to light the need for the use of complex techniques for purchasing / production management, especially at the operational decision level (Kiran, 2019). In such a scenario, prior optimized operational planning becomes impressible for better use of the productive capacity and to avoid investment losses in unnecessary or unprofitable material. And, given the wide variety of products, it is crucial to start any planning by understanding the importance of all products marked by the company.

One of the approaches that is widely applied to clustering products according to their importance is the multicriteria ABC classification. The scientific literature broadly emphasizes the value of multicriteria ABC classification for inventory management and presents several multicriteria methods. The Analytical Hierarchy Process is one of the most common techniques applied for this purpose (Flores *et al.*, 1992; Altay Guvenir and Erel, 1998; Lolli *et al.*, 2014; Balaji and Kumar, 2014). Some recent studies also emphasize the importance of applying multicriteria analysis to strategic planning (*e.g.*, Barbosa de Paula *et al.*, 2022; de Moura Pereira *et al.*, 2023; Mariano Ribeiro *et al.*, 2023). Odu (2019) emphasizes that, when applying some multicriteria methods, it is crucial to pay particular attention to the objectivity factors of criteria weights. The author provides a detailed overview of different weighting methods applicable to multicriteria techniques.

In this work, we present a study with three companies from three different sectors, which market a wide variety of products, in some cases, highly personalized products. The interest of this study is to identify the principal products, that is, the products that each company must prioritize so that this information can guide the optimized operational planning. We opted for the method ABC for multicriteria classification and adopted the Analytic Hierarchy Process (AHP) (Saaty, 1987) to assign the weights to the different criteria. It is important to note that the Analytic Hierarchy Process derives the weights of each criterion based on the eigenvector of a pairwise comparison matrix, which is constructed manually according to an empirical evaluation. According to Saaty (1987), this matrix must be antisymmetric and have a consistency rate of less than 0.1. The author reports that a software package supporting the AHP, called Expert Choice, for the IBM PC, was used in his work for making eigenvector calculations and guiding the decision maker to improve matrix inconsistency if needed. During the execution of the work we present in this paper, we found that there is a substantial difficulty in the calculation of the eigenvector, as well as in the construction of consistent pairwise comparison matrices. Since we had no access to the Expert Choice software package, we developed an open-source COPSolver library for the Analytic Hierarchy Process and multicriteria ABC classification based on a simple algorithm for forcing the consistency of such matrices. We present this algorithm in this paper. We coupled the Eigen library from eigen.tuxfamily.org to COPSolver for the eigenvectors calculation of the matrices. Also, we identified that it is possible to use different criteria types (cumulative sum, qualitative, and binary) when assigning weights to ABC classification, depending on each specific criterion chosen, and we observed that such an assignment generates a bias in the multicriteria ABC classification. Therefore, we also developed a new methodology for assigning weights in a balanced way for ABC classification, and we proposed a new multicriteria weighting equation for the multicriteria classification COPSolver library. We also present both propositions in this paper, as well as an in-depth analysis of the results found by the new library developed for COPSolver.

The rest of this paper is structured as follows. Section 2 presents the algorithm developed to force the consistency of pairwise comparison matrices. Section 3 explains the proposed approach for assigning the weights for the ABC classification and the equation for calculating the weights for the multicriteria classification. Section 4 briefly exhibits COPSolver software and the new library developed for multicriteria classification. Section 5 presents the results and analysis informing about the precautions someone must have when elaborating the COPSolver input file for multicriteria classification. Section 6 reports the credits in carrying out this work. Sections 7 and 8 conclude this article with conclusions and acknowledgments, respectively.

2. ALGORITHM FOR FORCING LOW CONSISTENCY RATE

Algorithm (1) illustrates the method developed to reduce the consistency rate (CR). This algorithm takes as input the pairwise comparison matrix ($M[m_{ij}]$) and the tolerance (tol) defined for the consistency rate and returns the matrix adjusted as well as the CR of this new matrix (see Saaty (1987) for more information on calculating the consistency rate).

Algorithm 1 forceConsistency()

Require: $tol, M[m_{ij}]$
Ensure: $CR < tol$
$n \leftarrow size(M[m_{ij}])$
$CR \leftarrow$ consistencyRate($M[m_{ij}]$)
topLeftCorner($CR, tol, M[m_{ij}]$)
bottomLeftCorner($CR, tol, M[m_{ij}]$)
return $CR, tol, M[m_{ij}]$

The topLeftCorner() function (alg. 3) performs a peer-to-peer comparison of each element of the pairwise matrix starting from the third row, $M[m_{\{sz\}j}]_{sz=3}^{n}$, with each element of the matrix $M[m_{jk}]_{j=1,k=j+1}^{n-1,n}$. In this comparison, the consistency of each pair is verified according to Alg. (2). If any inconsistency is found, the value of one of the elements is reduced or increased, seeking to improve the consistency rate. Initially, the reduction of values is done through the reduce() function. If, after the reduction, the convergence rate is still greater than the tolerance, the increment of values is made through the increase() function.

Algorithm 2 consistency checking

Require: $M[m_{ij}]$
if $m_{\{sz\}j} * m_{jk} = m_{\{sz\}k}$ **then**
$consistent \leftarrow 1$ ▷ values are consistent
else
$consistent \leftarrow 0$ ▷ values are not consistent
end if
return $consistent$

The bottomLeftCorner() function is similar to the topLeftCorner() function. In the topLeftCorner() function, the peer-to-peer comparison starts with the elements of the third row ($M[m_{\{sz\}j}]_{sz=3}$), and then the elements of the next rows are evaluated, following the order from top to bottom. In the case of the bottomLeftCorner() function, on the other hand, the

Algorithm 3 topLeftCorner()

Require: $CR, tol, M[m_{ij}]$
  if $CR \geq tol$ **then**
    for $sz \leftarrow 3, n$ **do**
      for $j \leftarrow 0, n-1$ **do**
        for $k \leftarrow j+1, n$ **do**
          $g \leftarrow 0$
          $s \leftarrow 0$
          if $m_{\{sz\}j} * m_{jk} > m_{\{sz\}k}$ **then**
            $g \leftarrow j$
            $s \leftarrow k$
          else if $m_{\{sz\}j} * m_{jk} < m_{\{sz\}k}$ **then**
            $g \leftarrow k$
            $s \leftarrow j$
          end if
          if $g > 0$ or $s > 0$ **then**
            reduce($CR, tol, sz, g, s, M[m_{ij}]$)
            if $CR \leq tol$ **then**
              break
            else if $m_{\{sz\}g} > m_{\{sz\}s}$ **then**
              increase(sz,g,s)
              if $CR \leq tol$ **then**
                break
              end if
            end if
          end if
        end for
        if $CR \leq tol$ **then**
          break
        end if
      end for
      if $CR \leq tol$ **then**
        break
      end if
    end for
  end if
  return $CR, tol, M[m_{ij}]$

Algorithm 4 reduce()

Require: $CR, tol, n, g, s, M[m_{ij}]$
  while $m_{ng} * m_{gs} > m_{ns}$ and $m_{ng} \neq 0$ **do**
    $auxCR \leftarrow CR$
    $m_{ng}++$
    $m_{gn}--$
    $CR \leftarrow$ consistencyRate($M[m_{ij}]$)
    if $CR > auxCR$ **then**
      $m_{ng}--$
      $m_{gn}++$
      $CR \leftarrow$ consistencyRate($M[m_{ij}]$)
      break
    else if $CR <= tol$ **then**
      break
    end if
  end while
  return $CR, tol, M[m_{ij}]$

Algorithm 5 increase()

```
Require: CR, tol, n, g, s, M[m_ij], it(M[m_ij])
  while m_ng * m_gs < m_ns and it(m_ng) ≠ n − 1 do
    auxCR ← CR
    m_ns ++
    m_sn −−
    CR ← consistencyRate(M[m_ij])
    if CR > auxCR then
      m_ns −−
      m_sn ++
      CR ← consistencyRate(M[m_ij])
      break
    else if CR <= tol then
      break
    end if
  end while
  return CR, tol, M[m_ij]
```

pair-by-pair comparison is made starting with the elements of the anti-penultimate row ($sz = n - 2$), then the elements of the previous rows are evaluated, following the order from bottom to top.

3. ON MULTICRITERIA ABC CLASSIFICATION

As discussed earlier, in our study, we observed that one of the crucial points for correctly applying multicriteria ABC classification is correctly attributing the weights for the initial ABC classification, that is, assign weights to each product according to each criterion.

When we built the input data file, we considered three types of criteria for ABC analysis, cumulative sum (for billing and lead time criteria), qualitative, and binary criteria. While we were testing the solver, we noticed that an incorrect assignment of the weights can generate a strong bias in the multicriteria classification, since the criterion with the top percentage difference will always be dominant.

Therefore, to assign the weights, three procedures were adopted, according to the different nature of each type of criterion used.

In the case of the binary criteria, the choice of a binary parameters (0 and 1) results in a distribution of the percentage among the criteria that are critical. This seems to be consistent with the desired goal. However, in the case of the other criteria types, the consistency is no longer so clear.

We can verify this inconsistency through a brief analysis of the two criteria classified according to the cumulative sum. For the data collected from the furniture trades company, the product with the highest billing (242,280.00 reais) has a billing corresponding to 12% of the total amount; and a product with a longer lead time (30 days) represents 0.46% of the total lead time, that is, a percentage 0.25% higher than products with a lead time of 20 days (0.31%) and 0.35% higher than products with a lead time of 7 days (0.11%).

The question is: is the difference between the importance of a product with a 30-day lead time and a product with a 7-day lead time only 0.35%? This value can only be appreciated when compared with the difference in importance of 12% between the product with the highest and the product with the lowest billing.

Make a multicriteria classification for the billing and lead time criteria based only on the accumulated sum is like calculate a weighted average of the annual sales of vehicles and bananas, hoping that this average will have some meaning. For there to be real meaning in the weighted average found by the multicriteria method, it is necessary to apply some procedure to balance the weights assigned to each criterion.

Odu (2019) cites CRITIC as one of the methods applied for weight assignment in multicriteria classification. This method starts with normalizing the weights using the following equations:

$$\rho_{ij} = \frac{w_{ij} - w_j^{\min}}{w_j^{\max} - w_j^{\min}} \qquad i = 1, ..., m; j = 1, ..., n \qquad \text{for benefit criteria} \tag{1}$$

$$\rho_{ij} = \frac{w_j^{\max} - w_{ij}}{w_j^{\max} - w_j^{\min}} \qquad i = 1, ..., m; j = 1, ..., n \qquad \text{for cost criteria} \tag{2}$$

Where $w_j^{\min}$ and $w_j^{\max}$ are, respectively, the lowest and highest weights assigned to criterion j, w_{ij} is the weight and ρ_{ij} is the normalized weight of criteria j for product i.

The problem with this normalization method is that the largest values of the different criteria will have exactly the same weight. In the case of the companies studied, this may not correspond to the assessment of experts.

Algorithm 6 bottomLeftCorner()

```
Require: CR, tol, M[m_ij]
  if CR ≥ tol then
      for sz ← n − 2, 1 do
          for j ← 0, n − 3 do
              for k ← j + 1, n − 2 do
                  g ← 0
                  s ← 0
                  if m_{sz−1}j * m_jk > m_{sz−1}k then
                      g ← j
                      s ← k
                  else if m_{sz−1}j * m_jk < m_{sz−1}k then
                      g ← k
                      s ← j
                  end if
                  if g > 0 or s > 0 then
                      reduce(sz-1,g,s)
                      if CR <= tol then
                          break
                      else if m_{sz−1}g > m_{sz−1}s then encrease(sz-1,g,s)
                          if CR <= tol then
                              break
                          end if
                      end if
                  end if
              end for
              if CR <= tol then
                  break
              end if
          end for
          if CR <= tol then
              break
          end if
      end for
  end if
  return CR, tol, M[m_ij]
```

The solution that we adopted in this work for multicriteria classification with lead time and billing criteria, was inspired on the work of Williams (1984). A single measure was adopted for these two criteria (lead time billing weight) dividing the billing by the complement of the lead time for each product and then normalizing the weights.

In the case of qualitative criteria, the initial ABC classification was made using three weights, one weight assigned to group A products, $w(A)$, a second weight assigned to group B products, $w(B)$, and a third weight assigned to products C, $w(C)$, where $w(A) > w(B) > w(C)$. For qualitative criteria, $w(A)$, $w(B)$ and $w(C)$ must be assigned using the following steps:

- order the products, in descending order, according to their respective values for lead time billing;
- classify products into three groups, A, B and C, for each qualitative criterion;
- do $w(C) = 0$ for all group C products, for each qualitative criterion;
- for each qualitative criterion, do peer-to-peer comparison with the groups A and B products and the products ordered according to the lead time billing criterion, answering the following question: the degree of importance of the products of this group to the qualitative criterion is equivalent to what degree of importance of the other product evaluated according to the lead time billing criterion ?;
- assign to $w(A)$ and $w(B)$ the value of the lead time billing of the product with corresponding importance;

After the correct assignment of the weights for each product according to each criterion, Eqs. (3) and (4) can be used for calculation of multicriteria classification weights of each product, ρ_p:

$$LtBW(p) = \frac{\frac{b_p}{1+(lt^{\max}-lt_p)}}{\sum_{p=1}^{\text{NP}}\{\frac{b_p}{1+(lt^{\max}-lt_p)}\}}, \quad p = 1, ..., \text{NP} \tag{3}$$

$$\rho_p = (wb + wlt) * LtBW(p) + \sum_{q=1}^{\text{NQ}} w_{\sigma_q} * LtBW(e_{p\sigma_q}) + \sum_{b=1}^{\text{NB}} w_{\beta_b} * w_{p\beta_b}, \quad p = 1, ..., \text{NP} \tag{4}$$

where:
NP is the number of products;
NQ is the number of qualitative criteria;
NB is the number of binary criteria;
Σ is the set of qualitative criteria, $\Sigma = \{\sigma_q\}_{q=1}^{NQ}$;
B is the set of binary criteria, $\text{B} = \{\beta_b\}_{b=1}^{NB}$;
p is the index used to represent each product, $p = 1, ..., \text{NP}$;
c is the index used to represent each criterion of qualitative or binary type , $c \in \Sigma \cup \text{B}$;
$LtBW(p)$ is the lead time billing weight of product p;
b_p is the billing of product p;
lt_p is the of product p;
wb is the multicriteria weight of criterion billing.
wlt is the multicriteria weight of criterion lead time.
w_c is the multicriteria weight of criterion c.
w_{pc} is the normalized weight percentage of the product p according to criterion c;

4. RESULTS AND DISCUSSIONS

4.1 Analysis on the Algorithm for Adjusting Inconsistencies

Table 1 presents the modifications made by the software 'COPSolver: library for solving the multicriteria classification problem' in the pairwise comparisons matrix and the consequent changes in the consistency rate (CR) for the data collected from the three companies selected for this study.

Speaking about the CR, Tab. 1 clearly shows the inconsistencies before the modification and how the weight modifications made by the algorithm reflect the adjustments of these inconsistencies. For example, in the case of the plastic bag manufacturing company, the billing criterion is more important than the criticality criterion and much more valuable than the lead time criterion. Also, the criticality criterion is more important than the lead time criterion. These statements are coherent. However, the vector of the weights of this matrix clearly shows that the criticality criterion is less relevant than the lead time criterion, which is inconsistent with the two first statements. The assignment of the other weights related to criteria criticality and lead time causes this inconsistency. We can see from the input data matrix that the obsolescence, replaceability, and repairability criteria are more important than the criticality criterion but less valuable than the lead-time criterion. According to the initial statement (that criticality is more relevant than lead time), this new statement generates

Table 1: **Pairwise comparisons matrix and consistency rate changes for three companies (results found by COPSolver) - legend: sb = substitutability; lt = lead-time; rp = repairability; cr = criticality; ob = obsolescence; bl = billing; cm = commonality; CR = consistence rate; w = normalized weights vector.**

car mechanics company

	original data							adjusted						
	CR = 0.216							CR = 0.085						
	$w = (0.35, 0.26, 0.18, 0.11, 0.05, 0.03, 0.01)$							$w = (0.37, 0.26, 0.12, 0.12, 0.06, 0.05, 0.02)$						
	sb	lt	rp	cr	ob	bl	cm	sb	lt	rp	cr	ob	co	cm
sb	1.00	3.00	3.00	5.00	7.00	9.00	9.00	1.00	3.00	3.00	3.00	7.00	9.00	9.00
lt	0.33	1.00	3.00	5.00	7.00	9.00	9.00	0.33	1.00	3.00	3.00	5.00	9.00	9.00
rp	0.33	0.33	1.00	3.00	9.00	9.00	9.00	0.33	0.33	1.00	1.00	3.00	3.00	9.00
cr	0.20	0.20	0.33	1.00	5.00	9.00	9.00	0.33	0.33	1.00	1.00	3.00	3.00	9.00
ob	0.14	0.14	0.11	0.20	1.00	5.00	9.00	0.14	0.20	0.33	0.33	1.00	1.00	9.00
np	0.11	0.11	0.11	0.11	0.20	1.00	9.00	0.11	0.11	0.33	0.33	1.00	1.00	9.00
cm	0.11	0.11	0.11	0.11	0.11	0.11	1.00	0.11	0.11	0.11	0.11	0.11	0.11	1.00

furniture trades company

	original data						adjusted					
	CR = 0.136						CR = 0.096					
	$w = (0.07, 0.13, 0.26, 0.03, 0.48, 0.03)$						$w = (0.09, 0.16, 0.35, 0.03, 0.35, 0.03)$					
	lt	rp	cr	cm	bl	ob	lt	rp	cr	cm	bl	ob
lt	1.00	0.20	0.14	7.00	0.11	5.00	1.00	0.20	0.14	7.00	0.14	5.00
rp	5.00	1.00	0.33	5.00	0.14	3.00	5.00	1.00	0.33	5.00	0.33	3.00
cr	7.00	3.00	1.00	9.00	0.33	9.00	7.00	3.00	1.00	9.00	1.00	9.00
cm	0.14	0.20	0.11	1.00	0.11	1.00	0.14	0.20	0.11	1.00	0.11	1.00
bl	9.00	7.00	3.00	9.00	1.00	9.00	7.00	3.00	1.00	9.00	1.00	9.00
ob	0.20	0.33	0.11	1.00	0.11	1.00	0.20	0.33	0.11	1.00	0.11	1.00

plastic packaging manufacturing company

	original data						adjusted					
	CR = 0.625						CR = 0.085					
	$w = (0.39, 0.10, 0.22, 0.09, 0.12, 0.07)$						$w = (0.50, 0.18, 0.14, 0.06, 0.09, 0.03)$					
	np	cr	lt	ob	sb	rp	bl	cr	lt	ob	sb	rp
np	1.00	3.00	7.00	7.00	5.00	5.00	1.00	3.00	7.00	9.00	5.00	9.00
cr	0.33	1.00	3.00	0.20	0.20	0.20	0.33	1.00	3.00	3.00	1.00	5.00
lt	0.14	0.33	1.00	5.00	7.00	7.00	0.14	0.33	1.00	3.00	3.00	7.00
ob	0.14	5.00	0.20	1.00	0.33	3.00	0.11	0.33	0.33	1.00	1.00	3.00
sb	0.20	5.00	0.14	3.00	1.00	3.00	0.20	1.00	0.33	1.00	1.00	3.00
rp	0.20	5.00	0.14	0.33	0.33	1.00	0.11	0.20	0.14	0.33	0.33	1.00

the inconsistency of the pairwise comparisons matrix. As we can see in the adjusted matrix, the algorithm quickly corrects these inconsistencies and then the weight vector.

As we can see in Tab. 1, the pairwise comparison weights are adjusted primarily according to the weights assigned to the first three criteria. Thus, although there is a change in the pairwise comparison weights, which may be significant, the weights assigned to the first three criteria are preserved. The algorithm will change the weights of the other criteria to force the consistency of the pairwise comparisons matrix. Another significant observation is that the algorithm stops when it reaches the desired consistency rate. So, it is more likely that the algorithm changes the weights related to the fourth criterion and the next ones. Therefore, in the preparation of the input file the data of the criteria must be informed in such a way that the criteria are ordered in descending order according to their respective relevance.

For the data presented in Table 1, there was no concern with the correct ordering of the criteria. Based on the results and previous observations, we have reordered the criteria using their respective weights, initially defined by the normalized eigenvector of the original pairwise comparisons matrix (w in Tab. 1). Table 2 presents the modification of results after altering the criteria ordination on the input data.

Table 3 presents a comparison of the results using different methods on the data provided by the furniture trading company. In matrix PCM 02, the method used to force consistency was applied before the reordering of the criteria. In the case of matrix PCM 03, the same method was applied after reordering the criteria. This table also shows the matrix PCM 04 with adjustments made manually to the matrix PCM 01 after verifying the results found by COPSolver. As we can see, the COPSolver software provides an important help in the preparation of consistent pairwise comparison

Table 2: **Pairwise comparisons matrix and consistency rate changes for three companies (results found by COPSolver) - legend: sb = substitutability; lt = lead-time; rp = repairability; cr = criticality; ob = obsolescence; bl = billing; cm = commonality; CR = consistence rate; w = normalized weights vector.**

car mechanics company

	original data reordered							adjusted						
	CR = 0.216							CR = 0.085						
	$w = (0.35, 0.26, 0.18, 0.11, 0.05, 0.03, 0.01)$							$w = (0.37, 0.26, 0.12, 0.12, 0.06, 0.05, 0.02)$						
	sb	lt	rp	cr	ob	bl	cm	sb	lt	rp	cr	ob	co	cm
sb	1.00	3.00	3.00	5.00	7.00	9.00	9.00	1.00	3.00	3.00	3.00	7.00	9.00	9.00
lt	0.33	1.00	3.00	5.00	7.00	9.00	9.00	0.33	1.00	3.00	3.00	5.00	9.00	9.00
rp	0.33	0.33	1.00	3.00	9.00	9.00	9.00	0.33	0.33	1.00	1.00	3.00	3.00	9.00
cr	0.20	0.20	0.33	1.00	5.00	9.00	9.00	0.33	0.33	1.00	1.00	3.00	3.00	9.00
ob	0.14	0.14	0.11	0.20	1.00	5.00	9.00	0.14	0.20	0.33	0.33	1.00	1.00	9.00
np	0.11	0.11	0.11	0.11	0.20	1.00	9.00	0.11	0.11	0.33	0.33	1.00	1.00	9.00
cm	0.11	0.11	0.11	0.11	0.11	0.11	1.00	0.11	0.11	0.11	0.11	0.11	0.11	1.00

furniture trades company

	original data reordered						adjusted					
	CR = 0.136						CR = 0.082					
	$w = (0.48, 0.26, 0.13, 0.07, 0.03, 0.03)$						$w = (0.49, 0.27, 0.11, 0.06, 0.05, 0.03)$					
	bl	cr	rp	lt	ob	cm	bl	cr	rp	lt	ob	cm
bl	1.00	3.00	7.00	9.00	9.00	9.00	1.00	3.00	7.00	9.00	9.00	9.00
cr	0.33	1.00	3.00	7.00	9.00	9.00	0.33	1.00	3.00	7.00	9.00	9.00
rp	0.14	0.33	1.00	5.00	3.00	5.00	0.14	0.33	1.00	3.00	3.00	5.00
lt	0.11	0.14	0.20	1.00	5.00	7.00	0.11	0.14	0.33	1.00	1.00	7.00
ob	0.11	0.11	0.33	0.20	1.00	1.00	0.11	0.11	0.33	1.00	1.00	3.00
sb	0.11	0.11	0.20	0.14	1.00	1.00	0.11	0.11	0.20	0.14	0.33	1.00

plastic packaging manufacturing company

	original data reordered						adjusted					
	CR = 0.625						CR = 0.094					
	$w = (0.40, 0.22, 0.12, 0.07, 0.10, 0.10)$						$w = (0.56, 0.21, 0.08, 0.07, 0.07, 0.02)$					
	bl	lt	sb	rp	ob	cr	bl	lt	sb	rp	ob	cr
bl	1.00	7.00	5.00	5.00	7.00	3.00	1.00	7.00	5.00	9.00	7.00	9.00
lt	0.14	1.00	7.00	7.00	5.00	0.33	0.14	1.00	3.00	5.00	5.00	9.00
sb	0.20	0.14	1.00	3.00	3.00	5.00	0.20	0.33	1.00	1.00	1.00	5.00
rp	0.20	0.14	0.33	1.00	0.33	5.00	0.11	0.20	1.00	1.00	1.00	5.00
ob	0.14	0.20	0.33	3.00	1.00	5.00	0.14	0.20	1.00	1.00	1.00	5.00
cr	0.33	3.00	0.20	0.20	0.20	1.00	0.11	0.11	0.20	0.20	0.20	1.00

matrices. We also found that it is important to perform the ordering of the criteria before adjusting the matrix seeking better consistency, since the weights assigned to the most relevant criteria should preferably be maintained. It is possible to verify in these tables that the reordering before the application of the method to force consistency causes the changes to be more distributed and are carried out in the weights relative to the least important criteria. Finally, we observe that the ordering of the criteria also helps in the manual adjustment of the pairwise comparison matrices, since the presentation of these tables with the ordered criteria facilitates the analysis of the weights. For multicriteria classification of items, the pairwise comparison matrix PCM 03 was used. However, in practical cases it is important to have a final assessment of the responsible employee and the matrix used for ABC classification can be a final matrix manually updated by the employee based on the results found by COPSolver.

4.2 Analysis On The New ABC Multicriteria Classification Method

5. DISCUSSION AND FINAL REMARKS

6. AGRADECIMENTOS

Se houver, esta seção deve ser colocada antes da lista de referências.

Table 3: **Pairwise comparisons matrix and consistency rate changes for three companies (results found by COPSolver) - legend: sb = substitutability; lt = lead-time; rp = repairability; cr = criticality; ob = obsolescence; bl = billing; cm = commonality; CR = consistence rate; w = normalized weights vector.**

furniture trades company

PCM 01 - original data reordered

CR = 0.136

$w = (0.48, 0.26, 0.13, 0.07, 0.03, 0.03)$

	bl	cr	rp	lt	ob	cm
bl	1.00	3.00	7.00	9.00	9.00	9.00
cr	0.33	1.00	3.00	7.00	9.00	9.00
rp	0.14	0.33	1.00	5.00	3.00	5.00
lt	0.11	0.14	0.20	1.00	5.00	7.00
ob	0.11	0.11	0.33	0.20	1.00	1.00
sb	0.11	0.11	0.20	0.14	1.00	1.00

PCM 02 - PCM 01 adjusted and than reordered

CR = 0.096

$w = (0.35, 0.35, 0.16, 0.09, 0.03, 0.03)$

bl	cr	rp	lt	ob	cm
1.00	1.00	3.00	7.00	9.00	9.00
1.00	1.00	3.00	7.00	9.00	9.00
0.33	0.33	1.00	5.00	3.00	5.00
0.14	0.14	0.20	1.00	5.00	7.00
0.11	0.11	0.33	0.20	1.00	1.00
0.11	0.11	0.20	0.14	1.00	1.00

PCM 03 - PCM 01 reordered and than adjusted

CR = 0.082

$w = (0.49, 0.27, 0.11, 0.06, 0.05, 0.03)$

	bl	cr	rp	lt	ob	cm
bl	1.00	3.00	7.00	9.00	9.00	9.00
cr	0.33	1.00	3.00	7.00	9.00	9.00
rp	0.14	0.33	1.00	3.00	3.00	5.00
lt	0.11	0.14	0.33	1.00	1.00	7.00
ob	0.11	0.11	0.33	1.00	1.00	3.00
sb	0.11	0.11	0.20	0.14	0.33	1.00

PCM 01 - manually adjusted based on COPSolver results

CR = 0.082

$w = (0.50, 0.25, 0.12, 0.08, 0.03, 0.03)$

bl	cr	rp	lt	ob	cm
1.00	3.00	7.00	9.00	9.00	9.00
0.33	1.00	3.00	5.00	9.00	9.00
0.14	0.33	1.00	3.00	5.00	5.00
0.11	0.20	0.33	1.00	5.00	5.00
0.11	0.11	0.20	0.20	1.00	1.00
0.11	0.11	0.20	0.20	1.00	1.00

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new ABC Multcriteria Classification with AHP

car mechanics company

75 sales between October 2020 and July 2023

	quant.	%	cutoff
A	10	23.81 %	80 %
B	15	35.71 %	95 %
C	17	40.48 %	100 %

furniture trades company

254 sales between

	quant.	%	cutoff
A	59	23.23 %	79.78 %
B	56	22.05 %	94.81 %
C	139	54.72 %	100.00 %

plastic packaging manufacturing company

5,967 sales between November 2019 and February 2023

	quant.	%	cutoff
A	128	5.49 %	
B	726	31.12 %	
C	1,479	63.39 %	

Table 4: ABC multicriteria classifications for three companies (results found by COPSolver)

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8. CRediT AUTHORSHIP CONTRIBUTION STATEMENT

T.B. Fraga: Conceptualization, Methodology, Software, Validation, Formal analysis, Investigation, Data Curation, Writing – original draft, Writing – review & editing, Supervision, Project administration. B.M. Cavalcanti: Investigation. A.M.D.Silva: Investigation. E.L.R. Silva: Investigation.

9. RESPONSABILIDADE AUTORAIS

Os autores são os únicos responsávelis pelo conteúdo deste trabalho.