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# Supply Chain Management (SCM): an Analysis based on the CRITIC-GRA-3N Method in the selection of auto parts suppliers for an auto parts dealer in the city of Guaratinguetá

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**Abstract**

This study aims to help improve the Supply Chain Management (SCM) of an auto parts dealership in the city of Guaratinguetá-SP. To fulfill the objective, the method used was CRITIC-GRA-3N. This new method was used to select and rank suppliers/distributors of automotive parts for the dealership object of this study. This new method was capable of selecting and ordering alternative suppliers/distributors of automotive parts in a simple, useful and effective way. Furthermore, the results showed that the new method is more consistent than the original CRITIC and GRA methods. The objective of the study was achieved because, through the new CRITIC-GRA-3N method, this work was able to help improve the Supply Chain Management (SCM) of the auto parts dealership.



*Keywords:* Type your keywords here, separated by semicolons ;

## 1. Introduction

The selection of actors that make up the Supply Chain of the auto parts sector (suppliers, distributors and resellers) plays an important role in Supply Chain Management (SCM). Thus, the concept of Supply Chain Management (SCM) becomes crucial for delineating this selection of suppliers and distributors. In this way, SCM is a way of


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interconnecting suppliers, factories, warehouses and stores so that products arrive in the right quantity, in the right place and at the right time, ensuring the strategic integration of the supply chain [1]. In this sense, according to [2], in today's globalized common market, supplier selection plays a very important role in increasing production and business costs. [3] says that the essence of the supplier selection process is a complex Multicriteria Decision Support problem that addresses qualitative and quantitative factors that can conflict due to incomplete and uncertain information.

In this context, according to the authors [4] to [12], Multicriteria Decision Support (AMD) methods are used to solve supplier selection problems in Supply Chain Management. Thus, according to [13] to [38], in the AMD methods, the aim is to build models that deal with subjective value judgments, that is, it is assumed to accept that subjectivity is a desirable element and will be present throughout the decision process and, therefore, the structure of decision-makers' values is associated with the existing criteria that will be used in evaluating the alternatives.

In this study, the authors used the recent CRITIC-GRA-3N method to select and order suppliers of automotive parts for an auto parts dealer located in the city of Guaratinguetá (São Paulo – Brazil). According to the authors [39], the CRITIC (CRiteria Importance Through Intercriteria Correlation) method is used to generate the weights and the GRA (Grey Relational Analysis) method is used to order the alternatives. In this new CRITIC-GRA-3N method, in addition to the previous steps that make up the methods already established in the literature, the authors inserted a third normalization to give more consistency to the method.

## 2. Problem description

The company AUTOPEÇAS GW has been an auto parts dealer in the city of Guaratinguetá-SP for 30 years and seeks to become a leader in the auto parts market in the region where it operates. For this, it aims to improve the Management of the Supply Chain in which it operates. In this sense, she recognizes that the selection of suppliers and distributors plays an important role in Supply Chain Management, as a poor choice of these will negatively impact its business. Thus, this study aims to assist this company in choosing and ordering distributors and suppliers that will compose its Supply Chain through a Decision Support Method called CRITIC-GRA-3N.

### *2.1. Structuring the Problem*

To structure the problem object of this study, the following tools were used the Decision-Making Framework. According to [40] the Decision-Making Framework is a tool that assists in the organization and systemic vision of a project, in order to make strategic decisions, in addition also assists decision making to direct what would be decided at a later point. To structure the Decision-Making Framework, a Brainstorm was carried out with the CEO of the auto parts dealer company object of this study and with the authors of this study. During the Brainstorm, several subjects were discussed, enabling the structuring of the Table presented in Fig 1.

In addition, the CEO reported that the main Systems for The Auto Parts Lines are the Systems of: Cooling, Exchange and Differential, Steering, Brakes, Electronic Injection, Motor, Suspension and Electric. For this work, only one of them was chosen, which was the Suspension System, but the proposed methodology and method can be used in the choice or ordination of any of these Automotive Systems and also with other criteria and alternatives.

Table 1. Criteria versus Alternative

| Criteria | Alternative |
|---|---|
| Price | Company 1 |
| Deadline Delivery | Company 2 |
| After Sales | Company 3 |
| Geographic Location | Company 4 |
| E-Commerce | Company 5 |
| Warranty | |

Table 1 shows that in the Alternatives is presented a fictitious name for the suppliers / distributors of auto parts that will make up the Supply Chain of the reseller company object of this study.

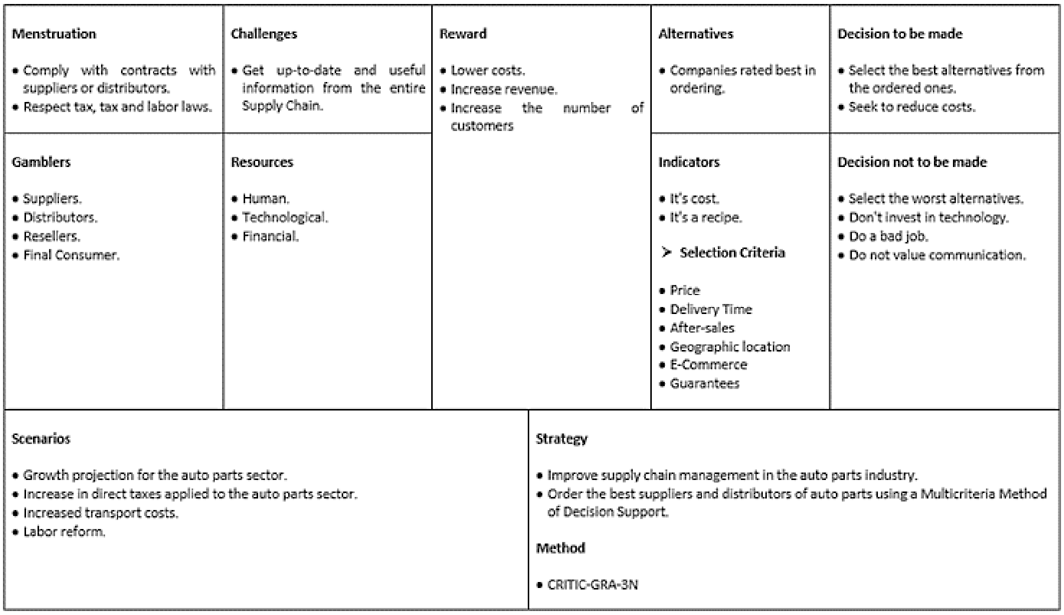

Fig. 1. Decision-Making Board

## 3. Methodology

The authors carried out a Brainstorm with the CEO of the auto parts dealership that is seeking to improve the Supply Chain Management in which it operates. During this Brainstorm, the authors and the CEO of the company, who has more than thirty years of experience in the auto parts area, arrived at the result of the Criteria and Alternatives that can be seen in Item 2 of this study. Then, with this information obtained, the data were inserted into the computational platform (https://critic-gra-3n.streamlit.app/) that was created with the purpose of putting the CRITIC-GRA-3N method into practice. This part of the study is presented in Item 4 (Solution Proposal) together with the mathematical axiomatics of the method. After entering the data on this platform, the software was executed and returned the results that were presented in Item 5 (Discussion of Results) of this study.

## 4. Solution Proposal

### *4.1. CRITIC-GRA-3N method*

The CRITIC-GRA-3N method is a hybrid method proposed by [39] derived from the original CRITIC methods (CRiteria Importance Through Intercriteria Correlation) and the GRA method (Grey Relational Analysis), but with a second and third normalization. Thus, this method is the combination of the CRITIC method, with the objective of calculating the weights, together with the GRA method, which has the purpose of ordering the alternatives [39]. According to this author, supported by this combination of methods, three orders are used: the first being the native normalization of the GRA method, the second is the normalization based on the hypothesis that the values established by the attributes behave in a Gaussian way within each criterion and the third is the normalization used in the first three sorting to calculate the averages [39]. Thus, it is essential to know the original CRITIC and GRA methods.

#### *4.1.1. Criteria Importance Through Intercriteria Correlation (CRITIC)*

According to [41], the authors Diakoulaki et al. (1995) proposed the CRITIC method to generate objective weights of relative importance in multicriteria problems. According to [39], the steps of the CRITIC method are creation of the decision matrix, normalization using equation (1) and (2), when monotonic of Profit and Cost, respectively:

$$x_{ij} = \frac{r_{ij} - r_i^-}{r_i^+ - r_i^-} \; ; i = 1, \dots, m, j = 1, \dots, n \tag{1}$$

$$x_{ij} = \frac{r_{ij} - r_i^+}{r_i^- - r_i^+} \; ; i = 1, \dots, m, j = 1, \dots, n \tag{2}$$

After that, the Correlation Coefficient is calculated using equation 3:

$$\rho jk = \frac{\sum_{i=1}^{m}(x_{ij} - \overline{x_j})(x_{ik} - \overline{x_k})}{\sqrt{\sum_{i=1}^{m}(x_{ij} - \overline{x_j})^2 \sum_{i=1}^{m}(x_{ik} - \overline{x_k})^2}} \tag{3}$$

Then, the C Index is calculated. For this, first the standard deviation of each attribute is obtained by means of equation (4), followed by the calculation of the C Index by equation (5):

$$\sigma_j = \sqrt{\frac{1}{n-1}\sum_{j=1}^{n}(x_{ij} - \overline{x_j})^2} \; ; i = 1, \dots, m \tag{4}$$

$$C_j = \sigma_j \sum_{k=1}^{n}(1 - \rho jk) \; ; j = 1, \dots, n \tag{5}$$

Finally, the attribute weights are calculated by equation (6), establishing them in descending ranking:

$$W_j = \frac{C_j}{\sum_{j=1}^{n} C_j} \; ; j = 1, \dots, n \tag{6}$$

*4.1.2. Grey Relational Analysis (GRA)*

According to [42] apud Li et al. (2007), the GRA method uses a decision-making under uncertainty approach and was found to be superior to comparable methods in the mathematical analysis of systems with incomplete information. The steps of the GRA method are: creation of a Decision Matrix. From there, the values are normalized using equation (7) when Profit is monotonic and equation (8) when Cost is monotonic.

$$x_{ij} = \frac{y_{ij} - min(y_{ij})}{max(y_{ij}) - min(y_{ij})} \tag{7}$$

$$x_{ij} = \frac{max(y_{ij}) - y_{ij}}{max(y_{ij}) - min(y_{ij})} \tag{8}$$

After that, a Reference Sequence is generated by equation (9) to compare the performance of all normalized values. In this Sequence, the closer the normalized value is to the value 1, the better its performance.

$$(x_{01}, x_{02}, \dots, x_{0j}, \dots, x_{0n}) = (1,1, \dots, 1, \dots, 1) \tag{9}$$

The Gray Relational Coefficient, calculated by equation (10), establishes how close the $X_{ij}$ is to the reference value $X_{0j}$.

$$\gamma(x_{0j}, x_{ij}) = \frac{(\Delta_{min} + \Delta_{max})}{(\Delta_{ij} + \Delta_{max})} \tag{10}$$

Where the values of Delta $\Delta ij$ and *min* and *max* are established by equation (11):

$$\Delta_{ij} = |x_{0j} - x_{ij}|$$
$$\Delta_{min} = min\{\Delta_{ij}, i = 1, 2, \ldots, m\,; j = 1, 2, \ldots, n\}$$
$$\Delta_{max} = max\{\Delta_{ij}, i = 1, 2, \ldots, m\,; j = 1, 2, \ldots, n\} \tag{11}$$

Thus, the Relational Gray Degree is a weighted sum of the gray relational coefficients, weighted by each criterion, and can be calculated using (12):

$$\tau(x_0, x_i) = \sum_{j=1}^{n} w_j\, \gamma(x_{0j}, x_{ij}) \tag{12}$$

Finally, there is a descending ranking of alternatives.

*4.1.3. Second Normalization*

The new CRITIC-GRA-3N method introduced two normalizations to the original method. The Second Normalization was added to the method based on the hypothesis that the values established by the attributes behave in a Gaussian way within each criterion. Thus, Priority observed from the presumption of Gaussian attitude of the alternatives, is based on the use of normalization based on the hypothesis that the values established by the attributes behave in a Gaussian way within each criterion.

Thus, according to [39] apud Park (2017), equation (13) used to calculate the probability *P* of any attribute *x* being less than or equal to the value established in the decision matrix, represents *pij*, of the normalized matrix.

$$p_{ij} = F(x) = F(x \le r_{ij}) = \int_{-\infty}^{r_{ij}} \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{1}{2}\left(\frac{\lambda-\mu}{\sigma}\right)^2} d\lambda \tag{13}$$

*4.1.4. Third Normalization*

Due to the need to build two more orderings, which refer to the arithmetic mean and the geometric mean, the authors added a 3rd Normalization. Thus, according to the authors, the first 3 rankings are obtained by the results of the following methods:

1ª – CRITIC-GRA;
2ª – CRITIC-GRA (with the second normalization); It is
3ª – Sum product of the weight obtained by the CRITIC method and the matrix generated by the 2ª normalization.

$$\nu = \frac{a_{ij}}{\sum a_{ij}} \tag{14}$$

According to the authors, at this moment equation (14) is used in order to normalize the first three orders separately, maintaining the proportionalities between them. After these 3 sorting, another normalization is performed, applying the arithmetic and geometric means, to obtain the last two sorting.

### *4.2. Case study*

As seen in Item 2, the company AUTOPEÇAS GW aims to improve the Management of the Supply Chain in which it operates. In this same Item, the Criteria and Alternatives that make up the Decision Matrix, presented in Table 2, were raised. For the E-Commerce Qualitative Criterion, a 5-point Likert-type scale was used, ranging from: (1) Very Bad, (2) Bad, (3) Neutral, (4) Good, and (5) Very Good. According to [43], the Likert scale has several advantages, it is easy to build and apply, respondents quickly understand how to use the scale, which makes it suitable for interviews.

Table 2. Decision Matrix

| | Company 1 | Company 2 | Company 3 | Company 4 | Company 5 |
|---|---|---|---|---|---|
| Price (R$) | 1087,43 | 1214,4 | 1380 | 1317,84 | 1299 |
| Delivery Time (days) | 2 | 2 | 3 | 3 | 2 |
| After Sales (hours) | 2 | 2 | 1,5 | 3 | 5 |
| Location (km) | 93,4 | 92,6 | 179 | 194 | 95,9 |
| E-Commerce (Likert) | 4 | 3 | 4 | 5 | 3 |
| Warranty (months) | 6 | 5 | 6 | 6 | 4 |

#### *4.2.1. Application of the CRITIC-GRA-3N Method through the Computational Platform*

Inserted the data in the platform, it will generate the Decision Matrix and the user must fill this Matrix with the cardinal data previously collected. Once this is done, the user must confirm the execution of the software so that it performs the calculations and presents the results.

Table 3. Normalized Ordination

| 1ª Ordination CRITIC + GRA | | 2ª Ordination GRA + 2ª | | 3ª Ordination 2ª Normalization | |
|---|---|---|---|---|---|
| Company 1 | 0,9109 | Company 1 | 0,9309 | Company 1 | 0,7402 |
| Company 2 | 0,7868 | Company 2 | 0,8228 | Company 2 | 0,5641 |
| Company 3 | 0,6631 | Company 3 | 0,7353 | Company 3 | 0,4189 |
| Company 4 | 0,6853 | Company 4 | 0,7538 | Company 4 | 0,4322 |
| Company 5 | 0,6864 | Company 5 | 0,7407 | Company 5 | 0,3992 |

Table 4. Normalization of Orders

| Normalization 1ª CRITIC + GRA | | Normalization 2ª GRA + 2ª | | Normalization 3ª GRA + 2ª | |
|---|---|---|---|---|---|
| Company 1 | 0,244 | Company 1 | 0,2337 | Company 1 | 0,2898 |
| Company 2 | 0,2108 | Company 2 | 0,2066 | Company 2 | 0,2208 |
| Company 3 | 0,1777 | Company 3 | 0,1846 | Company 3 | 0,164 |
| Company 4 | 0,1836 | Company 4 | 0,1892 | Company 4 | 0,1682 |
| Company 5 | 0,1839 | Company 5 | 0,1859 | Company 5 | 0,1536 |

Table 5. Geometric Mean of Normalized Alternatives and 5 ª Ordering

| 5ª Ordination | Geometric Mean | Ranking |
|---|---|---|
| Company 1 | 0,2547 | 1 |
| Company 2 | 0,2126 | 2 |
| Company 4 | 0,1752 | 3 |
| Company 3 | 0,1805 | 4 |
| Company 5 | 0,1748 | 5 |

Finally, Table 7 presents all the Orders that the new method proposes.

Table 6. Ordination

| 1ª Ordination CRITIC-GRA | | 2ª Ordination CRITIC-GRA-2N | | 3ª Ordination 2N-CRITIC | | 4ª Ordination Arithmetic Mean | | 5ª Ordination Geometric Mean | |
|---|---|---|---|---|---|---|---|---|---|
| Company 1 | 0.9109 | Company 1 | 0.9309 | Company 1 | 0.7402 | Company 1 | 0.2558 | Company 1 | 0.2547 |
| Company 2 | 0.7868 | Company 2 | 0.8228 | Company 2 | 0.5641 | Company 2 | 0.2127 | Company 2 | 0.2126 |
| Company 5 | 0.6864 | Company 4 | 0.7538 | Company 4 | 0.4322 | Company 4 | 0.1807 | Company 4 | 0.1805 |
| Company 4 | 0.6853 | Company 5 | 0.7407 | Company 3 | 0.4189 | Company 3 | 0.1754 | Company 3 | 0.1752 |
| Company 3 | 0.6631 | Company 3 | 0.7353 | Company 5 | 0.3992 | Company 5 | 0.1754 | Company 5 | 0.1748 |

## 5. Conclusion

With the results presented, it can be observed that Company 1 was in 1st place in all rankings, that is, this Company should be chosen as the main supplier of auto parts for the company object of this study. Company 2 ranked 2nd in all rankings. Thus, this Company should be chosen if Company 1 cannot supply auto parts for any reason. In addition, these Companies, in relation to the others, have a much higher score, that is, they must certainly be the main suppliers and only if they cannot supply auto parts should the other options ordered by the method be analyzed. CRITIC-GRA-3N. In view of this, with regard to the positions of Company 3, Company 4 and Company 5 in the Ordering of the method, it is verified, through Table 5, that there are alternations between them, that is, with regard to these companies, the decision maker must have greater attention in its choice, in case Company 1 and Company 2 cannot be the suppliers at the moment.

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