



# A Square-Root Based Evaluation Method for Engineering Personnel Selection: A Case Study of Quality Engineer Selection

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**Abstract:** Personnel selection represents one of the most important tasks of human resource management, while the selection of engineering personnel is of particular interest to the industrial manufacturing sector. This study dealt with the problem of selecting a quality engineer based on applications submitted in response to a job advertisement announced by a company that manufactured industrial equipment. The aim of the research is to demonstrate the robustness of a hybrid Multi-Criteria Decision-Making (MCDM) model based on the integration of the CRiteria Importance Through Intercriteria Correlation (CRITIC) method and the Square-Root based Evaluation Method (SREM). Such a model aims to reduce subjectivity in the decision-making process and serves as a supporting tool for company management in the personnel selection process. The results obtained from the case study demonstrated that the proposed model objectively and reliably identified the most suitable candidate, while taking into account different performance characteristics. The solution proved to be highly stable, since the sensitivity analysis revealed that even in the case where all criteria had equal importance, the best candidates remained at the top of the ranking list. Furthermore, this research indicated that the proposed CRITIC–SREM model could probably be a standard decision-support tool for decision-makers in personnel selection and the handling of similar problems.

**Keywords:** Personnel selection; Human resource management; Manufacturing; Quality engineer; CRiteria Importance Through Intercriteria Correlation; Square-Root based Evaluation Method

## 1 Introduction

The human resources (HR) department represents one of the most important departments in every business system. Regardless of the industry, the HR function is an essential component in achieving a company's strategic and operational goals. In practice, the responsibilities of the HR department, as well as its management, often extend beyond the boundaries of the department itself. HR managers play a strategically important role within the company, as they act as intermediaries between top management and the implementation of business strategy, as well as between top management and other managerial levels.

Besides planning and coordinating activities within its own functional area, the HR department is responsible for providing managerial support to other business functions. Therefore, human resource management can be viewed not only as a separate business function within an organization, but also as a much broader and more complex concept that permeates the entire business system. The HR function has to participate inevitably in the development and operation of all other business functions, while simultaneously depending on them. Indeed, some authors suggested that the performance of employees significantly affected the performance and business success of a company [1].

The HR department in every company possesses its own specific characteristics and differs, at least to a certain extent, from the same department in another company. In fact, the HR department can vary significantly depending on the size of the business system (i.e., the number of employees), the industry sector, ownership structure, organizational culture, geographical area (country), as well as other important business characteristics and operating conditions.

One of the important strategic tasks faced by the HR department of every company is employing the right person for the appropriate position. In fact, the problem of selecting job candidates represents a highly significant activity involving the entire expert team of the company, rather than only the HR department. The selection of the optimal candidate among numerous available alternatives can be characterized as a complex process that very often involves the analysis of conflicting objectives and characteristics [2]. The selected candidate should possess the potential, talent, knowledge, and skills that could contribute to the company in various aspects of its operations.

It is noteworthy that potential candidates undergo several thorough evaluations, providing the HR department with the opportunity to select the most suitable applicants, naturally in cooperation with experts from the specific domain related to the vacant position. However, some authors pointed out that certain candidate selection criteria were not always easily measurable or observable, especially when it came to candidates' creativity, organizational and leadership abilities [3]. Despite the tendency and intention to objectively consider all circumstances related to the candidates, the selection process is still burdened by the subjective impressions of the committee members, including both HR personnel and domain experts. For this reason, the need emerged for the development of Multi-Criteria Decision-Making (MCDM) models capable of ranking candidates based on objective criteria. Recent studies in this field have pointed out that hybrid MCDM models, which combine multiple methods and evaluation mechanisms, yielded valid results and more effectively overcame the problem of subjectivity [4]. Nevertheless, such models should serve only as decision-support tools rather than as strict rules in the final candidate selection process.

Precisely because HR departments often require support in decision-making processes, the motivation for conducting this research emerged. In this connection, this paper addressed the selection of a new quality engineer in a company operating within the industrial equipment manufacturing sector. The company announced a job vacancy with the aim of hiring a junior engineer who would work in the quality control department.

To solve this problem, a two-stage MCDM approach was applied. The criteria used for candidate evaluation were defined by company experts. Their weights were determined using the CRiteria Importance Through Intercriteria Correlation (CRITIC) method [5, 6], while candidate ranking was performed using the Square-Root based Evaluation Method (SREM) [7]. In the relevant literature, there is a consensus that the problem of engineer selection is very important in industry, as unsuitable personnel could have a negative impact on productivity and product quality [8]. The main idea behind the proposed approach was to objectively determine the weights of the evaluation criteria through the CRITIC method, while the SREM method enabled candidate ranking from three different perspectives. The first perspective focused on selecting the most consistent candidate, i.e., the candidate demonstrating stable and uniformly good performance across all considered criteria. The second perspective aimed to identify the candidate who excelled in the most significant criteria. Finally, the third perspective ensured a balanced and objective evaluation approach. Such an analysis was feasible via the SREM method, hence highly suitable for solving this type of personnel selection problem.

The aim of this research is to develop a model that would be useful not only for the HR department of this company, but also for other companies, particularly in the field of industrial manufacturing. The proposed model should serve as a decision-support tool for selecting the appropriate candidate, while being sufficiently flexible in terms of changes in the number of criteria and the evaluation procedure for candidates.

After the introductory section, Section 2 provides a literature review in the field of the personnel selection problem. Section 3 presents the proposed model along with the steps for applying the MCDM methods used. Section 4 contains the case study. Section 5 presents a discussion of the results obtained, while the final section provides the conclusions of the research.

## 2 Literature Review

In the relevant literature, the problem of personnel selection is very often tackled by MCDM methods [2]. In previous studies related to this topic, the authors clearly highlighted a growing trend in the use of hybrid MCDM models for this purpose [4, 9]. Apart from the above, there are studies in the literature in which authors provided a comparative overview of different MCDM approaches in this domain, thus emphasizing their importance in real business environments [10]. In addition to the classical application of such models, there are studies in which the authors introduced additional dimensions into the decision-making process. In the study, the authors [11] utilized the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) [12] method for the personnel selection problem, but also developed a so-called veto threshold concept, which automatically eliminated candidates with unacceptable scores according to the most important criteria.

When it came to the objective approach for determining the weights of criteria used in personnel selection, the Stepwise Weight Assessment Ratio Analysis (SWARA) [13] was often used in the literature. The authors used it in combination with different ranking methods [14–16]; the Additive Ratio Assessment (ARAS) [17] method was also used in other studies [15, 16].

The subjective approach was employed in the study [8], in which the author applied the Analytic Network Process (ANP) and TOPSIS methods in manufacturing systems. Similarly, the personnel selection problem, but only in the

field of public relations, was addressed by Chang [18]. A combination of the Decision Making Trial and Evaluation Laboratory (DEMATEL) and the Elimination and Choice Expressing Reality (ELECTRE) methods was applied in the study [19]. In the study [3], the authors used Ordered Weighted Averaging (OWA) [20] operators to aggregate data from multiple sources. From the perspective of broader application, the problem of personnel selection has been handled by various MCDM methods [21–26].

In the field of engineering and the personnel selection problem within this domain, several important studies can be highlighted. In the logistics domain, the TOPSIS method has been used for personnel selection [27, 28]. One of the few studies in which the CRITIC method was utilized for determining criteria weights was conducted by Tadić et al. [29], in combination with the TOPSIS method. The authors of this study stated that the illustrative example was adapted from Korkmaz [27]. In the textile industry domain, Danişan et al. [30] combined Analytic Hierarchy Process (AHP) and the Preference Ranking Organization Method for Enrichment Evaluations (PROMETHEE) [31].

A problem similar to the one considered in this study was addressed by Deliktaş and Üstün [32]. The focus of the research was the selection of an industrial engineer, which was carried out using a combined AHP–TOPSIS approach. In the automotive industry, the selection of members of an engineering team [33] responsible for performing Failure Mode and Effects Analysis (FMEA) [34] was conducted. In this study, the authors used the RANKing based on the Distances And Range (RADAR) method [35] for ranking candidates.

Despite the fact that numerous objective methods for determining criteria weights existed today, with different mathematical foundations [36–39], the CRITIC method has traditionally been one of the most widely used in the literature and has proven to be highly useful in situations requiring independent decision making. For this reason, it was selected for determining criteria weights in this study as well. On the other hand, the SREM method is a relatively new approach, still insufficiently explored in the literature, which has the capability to assess the reliability and robustness of the solution. In other words, it enables decision-makers to evaluate the ranking of alternatives from multiple perspectives, as already stated in the introductory section.

### 3 Methodology

The proposed methodology was based on criteria already existing in the relevant literature. These criteria were not adopted directly from a single source; instead, objective criteria that do not depend on subjective judgment were selected from several different sources [8, 15, 22, 29, 32]. Table 1 presents the criteria put into practice in this study, along with their explanations.

**Table 1.** Criteria used for candidate evaluation and their descriptions

| Label   | Criterion                      | Description                                                                                                                                                                                       |
|---------|--------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| $j = 1$ | Academic performance           | Average grade during studies.                                                                                                                                                                     |
| $j = 2$ | Level of education             | Completed three-year Bachelor's studies are assigned a score of 3, four-year Bachelor's studies are assigned a score of 4, and completed Master's studies are assigned a score of 5.              |
| $j = 3$ | General Engineering Competence | Taking a test in the field of general knowledge in engineering. The maximum number of points on the test is 100.                                                                                  |
| $j = 4$ | Quality Engineering Expertise  | Taking a test in the field of quality in industry. The maximum number of points on the test is 100.                                                                                               |
| $j = 5$ | Professional experience        | Work experience in engineering positions expressed in months. Considering that the candidates were young engineers, the period spent in professional internship had also been taken into account. |
| $j = 6$ | Foreign Language Skills        | Taking a test in English language proficiency for engineers. The maximum number of points on the test is 100.                                                                                     |

The candidates being evaluated could formally be represented by the set of indices  $1, \dots, i, \dots, I$ . The candidate selection procedure, which integrated the proposed CRITIC–SREM approach, was carried out through the following phases:

- Phase 1. Announcement of the job vacancy for a quality engineer;
- Phase 2. Applying for the job advertised in the job vacancy;
- Phase 3. Invitation to the job interview arranged by the HR department;
- Phase 4. Taking the eliminatory General Engineering Competence test (60+ points required to pass);
- Phase 5. Taking the Quality Engineering Expertise test;
- Phase 6. Taking the Foreign Language Skills test;
- Phase 7. Implementation of the proposed CRITIC–SREM approach for the evaluation of candidates;

- Phase 8. Final interview with candidates conducted by company experts from the quality domain; and
- Phase 9. Notification of candidates about the competition outcome.

In the remainder of this section, an overview of the steps for applying the MCDM methods, as well as the mathematical formulation of the problem, is provided.

### 3.1 Criteria Importance Through Intercriteria Correlation Method

In this study, the basic CRITIC method was used to determine the criteria weights. The main steps of this method are as follows:

Step 1: The decision matrix was formed, i.e., the values of the alternatives were defined with respect to each criterion. In this case, these were the data on the candidates. Formally, the decision matrix can be represented as follows:

$$[D_{ij}]_{I \times J} \quad (1)$$

where,

$i = 1, \dots, I$  denotes the candidate index;

$j = 1, \dots, J$  denotes the criterion index;

$I$  is the total number of candidates;

$J$  is the total number of criteria; and

$d_{ij}$  represents the original performance value of candidate  $i$  under criterion  $j$ .

Step 2: The values were normalized using linear normalization according to the following formula:

$$t_{ij} = \frac{d_{ij} - d_j^{\min}}{d_j^{\max} - d_j^{\min}} \quad (2)$$

Step 3: The value of standard deviation was calculated for each criterion,  $s_j$ .

Step 4: The correlation coefficient between each pair of criteria was determined,  $r_{jj'}$ .

Step 5: The non-normalized values of the criteria weights ( $W_j$ ) were determined:

$$W_j = s_j \cdot \sum_{j=1, \dots, J} (1 - r_{jj'}) \quad (3)$$

Step 6: The values were normalized and the final criteria weights ( $\omega_j$ ) were obtained:

$$\omega_j = \frac{W_j}{\sum_{j=1, \dots, J} W_j} \quad (4)$$

In Eqs. (2)–(4),  $t_{ij}$  is the normalized value of  $d_{ij}$ ,  $d_j^{\min}$  and  $d_j^{\max}$  are the minimum and maximum values of criterion  $j$ , respectively,  $s_j$  is the standard deviation of criterion  $j$ ,  $r_{jj'}$  is the correlation coefficient between criteria  $j$  and  $j'$ ,  $W_j$  is the non-normalized weight of criterion  $j$ , and  $\omega_j$  is the final normalized weight.

After normalization, the total sum of all criteria weights is equal to 1.

### 3.2 Square-Root Based Evaluation Method Method

In this study, the basic version of the SREM method was applied. The method is relatively new and has not yet been applied in the field of personnel selection. Furthermore, the standard procedure of the SREM method applied in this study is presented as follows:

Step 1: The same decision matrix as in the CRITIC method was used.

Step 2: The values were normalized and the normalized decision matrix was formed:

$$[M_{ij}]_{I \times J} \quad (5)$$

In the SREM procedure,  $m_{ij}$  denotes the normalized performance value of candidate  $i$  under criterion  $j$ .  $S_{ij}$  and  $R_{ij}$  represent the squared-transformed and root-transformed normalized values, respectively.

Normalization of values was performed depending on the type of criteria. Eq. (6) shows the normalization procedure for benefit-type criteria, while Eq. (7) shows the normalization procedure for cost-type criteria.

$$m_{ij} = \frac{d_{ij}}{\sum_{i=1}^I d_{ij}} \cdot 100 \quad (6)$$

$$m_{ij} = \frac{\frac{1}{d_{ij}}}{\sum_{i=1}^I \frac{1}{d_{ij}}} \cdot 100 \quad (7)$$

It should be noted that all criteria in this study are of the benefit-type.

Step 3: The elements of the squared-transformed normalized matrix were calculated:

$$[S_{ij}]_{I \times J} \quad (8)$$

where,

$$S_{ij} = \frac{m_{ij}^2}{\sum_{i=1}^I m_{ij}^2} \quad (9)$$

Step 4: The elements of the root-transformed normalized matrix were calculated:

$$[R_{ij}]_{I \times J} \quad (10)$$

where,

$$R_{ij} = \frac{\sqrt{m_{ij}}}{\sum_{i=1}^I \sqrt{m_{ij}}} \quad (11)$$

Step 5: The elements of the  $\alpha$ -fused matrix were calculated:

$$[A_{ij}]_{I \times J} \quad (12)$$

where,

$$a_{ij} = \alpha \cdot S_{ij} + (1 - \alpha) \cdot R_{ij} \quad (13)$$

Step 6: The elements of the weighted  $\alpha$ -fused matrix were calculated:

$$[N_{ij}]_{I \times J} \quad (14)$$

where,

$$n_{ij} = a_{ij} \cdot \omega_j \quad (15)$$

Step 7: The final ranking index was calculated and the alternatives were ranked.

$$F_i = \sum_{j=1}^J n_{ij} \quad (16)$$

In Eqs. (12)–(16),  $a_{ij}$  is the fused normalized value obtained by combining  $S_{ij}$  and  $R_{ij}$ ,  $\alpha \in [0,1]$  is the fusion parameter controlling the relative contribution of the squared-transformed and root-transformed matrices,  $n_{ij}$  is the weighted fused value, and  $F_i$  is the final ranking index of candidate  $i$ . A higher  $F_i$  value indicates a better-ranked candidate.

The alternative with the highest value of the final ranking index was ranked first. The opposite also holds true.

#### 4 Case Study

The case study was conducted in a company operating in the industrial equipment manufacturing sector. The company is engaged in the design and production of hydraulic systems, devices, and assemblies. The headquarters of the company is located in western Serbia. Its products are primarily manufactured for the Serbian market, but also for the market of the European Union.

In the previous section, the procedure for candidate selection for the vacant quality engineer position was explained. First, a job advertisement was announced and remained open for one month. A total of 11 candidates applied for the position, of which 8 attended the interview arranged by representatives of the HR department.

Out of these eight candidates, seven passed the General Engineering Competence test as they had achieved 60 or more points. The candidates who passed this test proceeded to the second round, where they took the Quality Engineering Expertise and Foreign Language Skills tests. In this case, the candidates took an English language

test, specifically a test related to the use of English in engineering contexts. Table 2 details the decision matrix, in accordance with the first step of applying both MCDM methods.

**Table 2.** Decision matrix

| $i$     | $j = 1$ | $j = 2$ | $j = 3$ | $j = 4$ | $j = 5$ | $j = 6$ |
|---------|---------|---------|---------|---------|---------|---------|
| $i = 1$ | 8.17    | 3       | 95      | 80      | 9       | 75      |
| $i = 2$ | 7.19    | 4       | 90      | 95      | 6       | 70      |
| $i = 3$ | 8.43    | 5       | 70      | 80      | 14      | 80      |
| $i = 4$ | 9.07    | 3       | 90      | 65      | 11      | 80      |
| $i = 5$ | 8.08    | 5       | 95      | 75      | 23      | 80      |
| $i = 6$ | 6.57    | 3       | 85      | 70      | 10      | 75      |
| $i = 7$ | 6.67    | 3       | 75      | 55      | 15      | 70      |

In Step 2 of the CRITIC method, the values of the decision matrix elements were normalized, and the normalized decision matrix was formed, as presented in Table 3.

**Table 3.** Normalized decision matrix (CRiteria Importance Through Intercriteria Correlation (CRITIC))

| $i$     | $j = 1$ | $j = 2$ | $j = 3$ | $j = 4$ | $j = 5$ | $j = 6$ |
|---------|---------|---------|---------|---------|---------|---------|
| $i = 1$ | 0.640   | 0.000   | 1.000   | 0.625   | 0.176   | 0.500   |
| $i = 2$ | 0.248   | 0.500   | 0.800   | 1.000   | 0.000   | 0.000   |
| $i = 3$ | 0.744   | 1.000   | 0.000   | 0.625   | 0.471   | 1.000   |
| $i = 4$ | 1.000   | 0.000   | 0.800   | 0.250   | 0.294   | 1.000   |
| $i = 5$ | 0.604   | 1.000   | 1.000   | 0.500   | 1.000   | 1.000   |
| $i = 6$ | 0.000   | 0.000   | 0.600   | 0.375   | 0.235   | 0.500   |
| $i = 7$ | 0.040   | 0.000   | 0.200   | 0.000   | 0.529   | 0.000   |

The first element of the normalized decision matrix was calculated as follows:

$$t_{11} = \frac{8.17 - 6.57}{9.07 - 6.57} = 0.64$$

The standard deviation values for each criterion were calculated using the Data Analysis package in Microsoft Excel, and they are as follows:

$$\begin{aligned} s_1 &= 0.378 & s_2 &= 0.476 & s_3 &= 0.390 \\ s_4 &= 0.318 & s_5 &= 0.324 & s_6 &= 0.450 \end{aligned}$$

In the same manner, the correlation coefficients between each pair of criteria were calculated (Step 4), as presented in Table 4.

**Table 4.** Correlation coefficients between the criteria

| $i$     | $j = 1$ | $j = 2$ | $j = 3$ | $j = 4$ | $j = 5$ | $j = 6$ |
|---------|---------|---------|---------|---------|---------|---------|
| $i = 1$ | 1.000   | 0.280   | 0.216   | 0.118   | 0.158   | 0.780   |
| $i = 2$ | 0.280   | 1.000   | -0.154  | 0.462   | 0.546   | 0.445   |
| $i = 3$ | 0.216   | -0.154  | 1.000   | 0.307   | -0.055  | 0.081   |
| $i = 4$ | 0.118   | 0.462   | 0.307   | 1.000   | -0.386  | -0.062  |
| $i = 5$ | 0.158   | 0.546   | -0.055  | -0.386  | 1.000   | 0.486   |
| $i = 6$ | 0.780   | 0.445   | 0.081   | -0.062  | 0.486   | 1.000   |

By following Steps 5 and 6 of the described CRITIC procedure, the final criteria weights were determined:

$$\begin{aligned} \omega_1 &= 0.14 & \omega_2 &= 0.18 & \omega_3 &= 0.20 \\ \omega_4 &= 0.16 & \omega_5 &= 0.15 & \omega_6 &= 0.16 \end{aligned}$$

The first step was the construction of the decision matrix and it was identical to the CRITIC method (see Table 2). In the second step, normalization of the values was performed using linear percentage normalization. The normalized values are presented in Table 5.

**Table 5.** Normalized decision matrix (Square-Root based Evaluation Method (SREM))

| $i$     | $j = 1$ | $j = 2$ | $j = 3$ | $j = 4$ | $j = 5$ | $j = 6$ |
|---------|---------|---------|---------|---------|---------|---------|
| $i = 1$ | 15.079  | 11.538  | 15.833  | 15.385  | 10.227  | 14.151  |
| $i = 2$ | 13.271  | 15.385  | 15.000  | 18.269  | 6.818   | 13.208  |
| $i = 3$ | 15.559  | 19.231  | 11.667  | 15.385  | 15.909  | 15.094  |
| $i = 4$ | 16.740  | 11.538  | 15.000  | 12.500  | 12.500  | 15.094  |
| $i = 5$ | 14.913  | 19.231  | 15.833  | 14.423  | 26.136  | 15.094  |
| $i = 6$ | 12.126  | 11.538  | 14.167  | 13.462  | 11.364  | 14.151  |
| $i = 7$ | 12.311  | 11.538  | 12.500  | 10.577  | 17.045  | 13.208  |

The first element of the normalized decision matrix was calculated as follows:

$$m_{11} = \frac{8.17}{54.18} \cdot 100 = 15.079$$

Next, the elements of the squared-transformed normalized matrix (Step 3) and the root-transformed normalized matrix (Step 4) were calculated. Their values are listed in Tables 6 and 7, respectively.

**Table 6.** The squared-transformed normalized matrix

| $i$     | $j = 1$ | $j = 2$ | $j = 3$ | $j = 4$ | $j = 5$ | $j = 6$ |
|---------|---------|---------|---------|---------|---------|---------|
| $i = 1$ | 0.157   | 0.088   | 0.174   | 0.162   | 0.063   | 0.140   |
| $i = 2$ | 0.122   | 0.157   | 0.156   | 0.228   | 0.028   | 0.122   |
| $i = 3$ | 0.167   | 0.245   | 0.094   | 0.162   | 0.152   | 0.159   |
| $i = 4$ | 0.194   | 0.088   | 0.156   | 0.107   | 0.094   | 0.159   |
| $i = 5$ | 0.154   | 0.245   | 0.174   | 0.142   | 0.411   | 0.159   |
| $i = 6$ | 0.102   | 0.088   | 0.139   | 0.124   | 0.078   | 0.140   |
| $i = 7$ | 0.105   | 0.088   | 0.108   | 0.076   | 0.175   | 0.122   |

**Table 7.** The root-transformed normalized matrix

| $i$     | $j = 1$ | $j = 2$ | $j = 3$ | $j = 4$ | $j = 5$ | $j = 6$ |
|---------|---------|---------|---------|---------|---------|---------|
| $i = 1$ | 0.147   | 0.129   | 0.151   | 0.149   | 0.123   | 0.142   |
| $i = 2$ | 0.138   | 0.149   | 0.147   | 0.162   | 0.101   | 0.137   |
| $i = 3$ | 0.149   | 0.167   | 0.129   | 0.149   | 0.154   | 0.147   |
| $i = 4$ | 0.155   | 0.129   | 0.147   | 0.134   | 0.136   | 0.147   |
| $i = 5$ | 0.146   | 0.167   | 0.151   | 0.144   | 0.197   | 0.147   |
| $i = 6$ | 0.132   | 0.129   | 0.142   | 0.139   | 0.130   | 0.142   |
| $i = 7$ | 0.133   | 0.129   | 0.134   | 0.123   | 0.159   | 0.137   |

The calculation of the first element of the squared-transformed and root-transformed normalized matrix was performed as follows:

$$S_{11} = \frac{15.079^2}{1446.837} = 0.157$$

$$R_{11} = \frac{\sqrt{15.079}}{26.415} = 0.147$$

Table 8 details the elements of the  $\alpha$ -fused matrix (Step 5) in the case of compromise ranking when  $\alpha = 0.5$ . Table 9 yields the values of the weighted  $\alpha$ -fused matrix (Step 6).

**Table 8.** The  $\alpha$ -fused matrix ( $\alpha = 0.5$ )

| $i$     | $j = 1$ | $j = 2$ | $j = 3$ | $j = 4$ | $j = 5$ | $j = 6$ |
|---------|---------|---------|---------|---------|---------|---------|
| $i = 1$ | 0.152   | 0.109   | 0.162   | 0.155   | 0.093   | 0.141   |
| $i = 2$ | 0.130   | 0.153   | 0.151   | 0.195   | 0.064   | 0.130   |
| $i = 3$ | 0.158   | 0.206   | 0.112   | 0.155   | 0.153   | 0.153   |
| $i = 4$ | 0.174   | 0.109   | 0.151   | 0.120   | 0.115   | 0.153   |
| $i = 5$ | 0.150   | 0.206   | 0.162   | 0.143   | 0.304   | 0.153   |
| $i = 6$ | 0.117   | 0.109   | 0.141   | 0.131   | 0.104   | 0.141   |
| $i = 7$ | 0.119   | 0.109   | 0.121   | 0.100   | 0.167   | 0.130   |

**Table 9.** The weighted  $\alpha$ -fused matrix ( $\alpha = 0.5$ )

| $i$     | $j = 1$ | $j = 2$ | $j = 3$ | $j = 4$ | $j = 5$ | $j = 6$ |
|---------|---------|---------|---------|---------|---------|---------|
| $i = 1$ | 0.021   | 0.020   | 0.032   | 0.025   | 0.014   | 0.023   |
| $i = 2$ | 0.018   | 0.028   | 0.030   | 0.031   | 0.010   | 0.021   |
| $i = 3$ | 0.022   | 0.037   | 0.022   | 0.025   | 0.023   | 0.024   |
| $i = 4$ | 0.024   | 0.020   | 0.030   | 0.019   | 0.017   | 0.024   |
| $i = 5$ | 0.021   | 0.037   | 0.032   | 0.023   | 0.046   | 0.024   |
| $i = 6$ | 0.016   | 0.020   | 0.028   | 0.021   | 0.016   | 0.023   |
| $i = 7$ | 0.017   | 0.020   | 0.024   | 0.016   | 0.025   | 0.021   |

The first element of the  $\alpha$ -fused matrix was calculated as follows:

$$a_{11} = 0.5 \cdot 0.157 + (1 - 0.5) \cdot 0.147 = 0.152$$

The first element of the weighted  $\alpha$ -fused matrix was calculated as follows:

$$n_{11} = 0.152 \cdot 0.14 = 0.021$$

The final ranking index (Step 7), as well as the ranking of alternatives for different values of the  $\alpha$  parameter, is provided in Tables 10 and 11, respectively.

**Table 10.** Final ranking index

| $i$     | $F_i(\alpha = 0)$ | $F_i(\alpha = 0.25)$ | $F_i(\alpha = 0.5)$ | $F_i(\alpha = 0.75)$ | $F_i(\alpha = 1)$ |
|---------|-------------------|----------------------|---------------------|----------------------|-------------------|
| $i = 1$ | 0.139             | 0.137                | 0.135               | 0.132                | 0.130             |
| $i = 2$ | 0.139             | 0.138                | 0.138               | 0.137                | 0.137             |
| $i = 3$ | 0.147             | 0.150                | 0.154               | 0.157                | 0.161             |
| $i = 4$ | 0.140             | 0.137                | 0.135               | 0.133                | 0.131             |
| $i = 5$ | 0.157             | 0.170                | 0.183               | 0.197                | 0.210             |
| $i = 6$ | 0.135             | 0.129                | 0.123               | 0.117                | 0.112             |
| $i = 7$ | 0.134             | 0.128                | 0.122               | 0.116                | 0.110             |

**Table 11.** Ranking of alternatives

| $i$     | Rank ( $\alpha = 0$ ) | Rank ( $\alpha = 0.25$ ) | Rank ( $\alpha = 0.5$ ) | Rank ( $\alpha = 0.75$ ) | Rank ( $\alpha = 1$ ) |
|---------|-----------------------|--------------------------|-------------------------|--------------------------|-----------------------|
| $i = 1$ | 4                     | 5                        | 5                       | 5                        | 5                     |
| $i = 2$ | 5                     | 3                        | 3                       | 3                        | 3                     |
| $i = 3$ | 2                     | 2                        | 2                       | 2                        | 2                     |
| $i = 4$ | 3                     | 4                        | 4                       | 4                        | 4                     |
| $i = 5$ | 1                     | 1                        | 1                       | 1                        | 1                     |
| $i = 6$ | 6                     | 6                        | 6                       | 6                        | 6                     |
| $i = 7$ | 7                     | 7                        | 7                       | 7                        | 7                     |

The final ranking index for alternative  $i = 1$  in the case when  $\alpha = 0.5$  was calculated as follows:

$$F_1 = 0.021 + 0.020 + 0.032 + 0.025 + 0.014 + 0.023 = 0.135$$

The next section offers a detailed analysis of the obtained findings. The results are also discussed from both a methodological and a practical perspective, i.e., from the perspective of the company.



## 5 Discussion

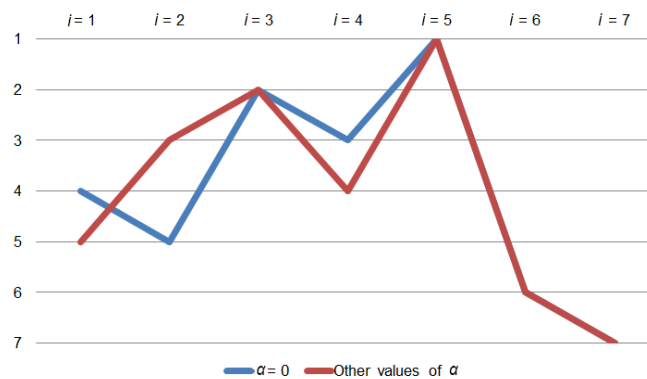
In the Case Study section, it was demonstrated that the hybrid CRITIC–SREM method could be successfully applied to the problem of personnel selection. The values of the criteria weights in this case depended on the standard deviation of the data within the criteria and the correlation coefficients between the criteria. The entire weighting procedure was based on objective parameters. Table 11 clearly shows that candidate  $i = 5$  is the best across all values of the  $\alpha$  coefficient. It can be concluded that, from both an engineering and educational perspective, this candidate was the most suitable. However, the final selection of the candidate depended exclusively on the HR department and other company experts involved in the recruitment and selection process. The proposed model should only serve as a decision-support tool, while the final decision should be made by them.

There was very little variation in the ranking only in the case when  $\alpha = 0$ ; in all other cases, there was complete overlap. Even this difference was very small as 0.89, as confirmed by the value of the Pearson correlation coefficient between the ranking when  $\alpha = 0$  and all other cases. This difference can be presented graphically, as shown in Figure 1.

Figure 1 displays deviations that occurred in the rotation of the 3<sup>rd</sup>, 4<sup>th</sup>, and 5<sup>th</sup> positions in the ranking. The first two candidates were ranked identically across all five cases and this offered the most important solution. Likewise, the last two candidates consistently occupied the same positions in the ranking. It could be concluded that the obtained ranking of candidates was highly stable.

For the purpose of additional sensitivity analysis, the ranking was examined under the assumption that all criteria had equal importance. The ranking of candidates under this assumption is graphically presented in Figure 2.

Based on Figure 2, it is clearly observable that candidate  $i = 5$ , under the assumption that all criteria had equal importance, remained objectively the best candidate for the quality engineer position. Furthermore, candidate  $i = 3$  was consistently ranked second across all considered scenarios. The situation also remained unchanged for the last two candidates in the ranking. As in the first case, the greatest variation was observed for candidate  $i = 2$ , who occupied positions ranging from 3<sup>rd</sup> to 5<sup>th</sup> place in the ranking, depending on the value of the  $\alpha$  parameter. This instability in the ranking was a consequence of instability in the candidate's performance values. There were criteria in which the candidate was among the top-ranked, criteria in which he was in the middle, as well as criteria in which he was ranked low. Therefore, the  $\alpha$  parameter had a significant influence on the ranking of this candidate.



**Figure 1.** A ranking deviation for  $\alpha = 0$  compared with other values



**Figure 2.** Sensitivity analysis: ranking with equal criteria weights

The final recommendation to the company management was to invite candidates  $i = 5$  and  $i = 3$  for the final interview, and if necessary, also candidate  $i = 4$ , who was ranked third in scenarios when candidate stability across the criteria had to be considered. Since this candidate had the highest average academic grade and achieved the best interpretation on the General Engineering Competence test, he might be given another opportunity. However, considering that candidate  $i = 5$  had completed master's studies, he might have a slight advantage over the other two candidates.

## 6 Conclusions

This paper addressed the personnel selection problem using a combined CRITIC–SREM approach. The specific problem considered in this study related to the selection of a new quality engineer in a company operating in the equipment manufacturing sector. The selection of new employees, including engineers, had a direct impact on the development of the company, and the proposed model aims to reduce the influence of subjective judgments of decision-makers by relying on mathematical objectivity. However, as emphasized in the paper, the proposed model should be used by decision-makers only as a supporting tool in making the final decision.

The main theoretical contributions of the paper can be summarized as follows: (1) the application of the CRITIC method as an objective tool for determining criterion weights; (2) the application of the SREM method, which enables testing the robustness and reliability of the obtained ranking; and (3) the implementation of a dual sensitivity analysis, both through different values of the  $\alpha$  parameter and through the case where weighted and unweighted criteria are considered. From a practical perspective, the contributions are as follows: (1) decision-makers are provided with a reliable decision-support tool that depends solely on the quality of input data; and (2) the model can be applied to other MCDM problems within the company.

Other than its contributions, the developed model also has certain limitations. First, its reliability and accuracy depend on the quality of the input data. The model neglects human intuition and cannot be used as a standalone decision-making tool. Accordingly, it is limited exclusively to quantitative criteria and does not consider a broader range of both quantitative and qualitative criteria. It is also imperative to note that the proposed model requires knowledge of basic mathematical statistics and related disciplines, which may represent a challenge for practitioners.

The HR department and company decision-makers consider that the proposed model makes the candidate selection process more transparent, measurable, and mathematically grounded. In the near future, the plan is to develop software based on the proposed CRITIC–SREM approach, which could be adapted to various MCDM problems, primarily in the HR domain. Furthermore, future research will focus on extending the model by applying fuzzy set theory, rough sets, or other approaches for modeling uncertainty.

## Author Contributions

Conceptualization, N.K. and D.M.; methodology, N.K.; validation, D.M.; formal analysis, N.K.; investigation, N.K.; resources, N.K.; data curation, D.M.; writing—original draft preparation, N.K.; writing—review and editing, D.M.; visualization, N.K.; supervision, D.M.; project administration, D.M. All authors have read and agreed to the published version of the manuscript.

## Data Availability

The data supporting our research results are included within the article.

## Conflicts of Interest

The authors declare no conflicts of interest.

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