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Development of A Decision Support System Algorithm for Human Resource Evaluation

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ABSTRACT

The study addresses a critical issue in the human resource planning process: the evaluation of human resources. The main objective is to develop a robust methodology and algorithm for human resource evaluation using multicriteria decision-making techniques. By integrating the Analytic Hierarchy Process (AHP) and ELECTRE methods, we offer a novel approach that enhances the precision and reliability of evaluations. To demonstrate the practical application and efficacy of our proposed methodology, we developed a decision support system prototype. This system serves as a proof of concept, illustrating how the methodology and algorithm can be integrated into real-world human resource planning processes.

1. Introduction

The decision-making process is constantly underway in any company or organization, the outcome of which is directly dependent on the company's future; therefore, the decision-making process is one of the most difficult tasks [1-6]. This type of task is analytical and requires some optimal assessment in certain situations. The solution to such tasks is to use a type of information system called a decision-making support system [7-9].

One of the important tasks of making decisions is personnel planning, which is a very responsible job because human resources are the most critical resource, which significantly determines the effectiveness of any organization, which is determined by the successful functioning of the organization. Human resources are important for the organization [7,8]; they determine the company's future strategy and human resources realize the strategies themselves. Human resources are involved in creating value-added in the company's management, but they can also cause a great deal of material damage to the company. Most of the mistakes made by human resources are

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attributable to their non-qualifications. To minimize human error, it is important to develop a decision support system for assessing and selecting human resources [10,11].

Despite many scientific studies, a significant gap remains in the effective evaluation of human resources. Traditional methods often lack the precision and adaptability required to assess the multifaceted attributes of human resources. Most existing models focus primarily on quantitative metrics, neglecting the critical qualitative aspects for comprehensive evaluations. Moreover, these models often fail to incorporate a multicriteria analysis approach, which is essential for addressing human resource attributes' diverse and complex nature.

This study seeks to develop a comprehensive human resources assessment model that integrates AHP and ELECTRE methods. The proposed model aims to enhance the evaluation process by providing a nuanced and multi-dimensional analysis of human resource attributes. This study contributes to developing more effective DSS for human resource management.

The AHP and ELECTRE methods [12,13] are well-regarded for their robustness in multicriteria decision-making. ELECTRE excels in handling outranking relations and is particularly effective in scenarios involving conflicting criteria [13]. Despite their proven efficacy, these methods have not been extensively applied in human resource evaluation.

2. Problem definition

The problem of assessing human resources is similar to that of a multicriteria decision-making analysis problem. The multicriteria decision-making analysis problem can be defined as follows [14-17]:

$$\begin{matrix} & C_1 & C_2 & C_3 & \cdots & C_n \\ A_1 & x_{11} & x_{12} & x_{13} & \cdots & x_{1n} \\ A_2 & x_{21} & x_{22} & x_{23} & \cdots & x_{2n} \\ A_3 & x_{31} & x_{32} & x_{33} & \cdots & x_{3n} \\ \vdots & \vdots & \vdots & \vdots & \ddots & \vdots \\ A_m & x_{m1} & x_{m2} & x_{m3} & \cdots & x_{mn} \\ & w_1 & w_2 & w_3 & \cdots & w_n \end{matrix} \tag{1}$$

Where $A_1, A_2, \ldots, A_m$ are alternatives, $C_1 C_2, \ldots, C_n$ are criteria with which alternative performance is measured, x_{ij} is the rating of alternatives concerning criterion C_j, w_j the weight of criterion C_j. Solving the multicriteria decision-making problem involves identifying one best alternative (decision) among all possible alternatives or ranking alternatives. As mentioned above, the problem of assessing and ranking human resources is similar to the problem of multicriteria decision analysis. The difference is that it is not based on fully expert assessments since some of the assessment criteria are evaluated using different types of testing; some of them are assessments by experts. Formulate the problem of assessing Human resources as follows (A, C, E, W) where A - Represents an infinite set of alternatives; the alternatives in our case are the human resources we want to assess; C- represents the criteria for assessing human resources, where experts evaluate assessment criteria from 1 to ks, while the criteria k + 1 to g are evaluated through different types of tests; E - $E = \{e_1, e_2, \ldots, e_v\}$ - To represent a set of experts who assess alternatives according to the relevant criteria. W- $W = \{w_1, w_2, \ldots, w_n\}$ - Represents the weights of the assessment criteria.

The main idea of the study is to develop a human resource assessment algorithm using the multicriteria analysis methods AHP and ELECTRE [9,18-20]. Specifically, AHP forms a weighting vector of assessment criteria, and the ELECTRE method is used to evaluate and rank alternatives.

3. Algorithm of the decision support system

Our proposed human resource assessment algorithm provides the following steps:
Step 1. Let's make a decision matrix.
Step 2. Determine criteria weights ($W = \{w_1, w_2, \dots, w_n\}$) using the AHP method.
Step 3: Let's normalize the matrix using the following formula:

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}} \tag{2}$$

Step 4. Let's define the weighted normalized matrix through the following formula:

$$\mathrm{V_{ij}} = R * W = \begin{bmatrix} r_{11} * w_1 & r_{12} * w_2 & \cdots & r_{1n} * w_n \\ r_{21} * w_1 & r_{22} * w_2 & \cdots & r_{2n} * w_1 \\ r_{31} * w_1 & r_{31} * w_2 & \cdots & r_{31} * w_1 \\ \cdots & \cdots & \cdots & \cdots \\ r_{m1} * w_1 & r_{m2} * w_2 & \cdots & r_{mn} * w_n \end{bmatrix} \tag{3}$$

Step 5. Find the sets of concordance and discordance intervals.
The concordance interval set is applied to describe the dominance query:

$$C_{ab} = \{j | x_{aj} \geq x_{bj}\} \tag{4}$$

The discordance interval set:

$$D_{ab} = \{j | x_{aj} < x_{bj}\} = j - C_{ab} \tag{5}$$

Calculation of the concordance interval matrix:

$$\mathrm{C} = \begin{bmatrix} - & c(1,2) & \cdots & c(1,m) \\ c(2,1) & - & \cdots & c(2,m) \\ c(3,1) & c(3,2) & - & c(3,m) \\ \cdots & \cdots & \cdots & \cdots \\ c(m,1) & c(m,2) & \cdots & - \end{bmatrix} \tag{6}$$

$$C_{ab} = \sum_{j \epsilon C_{ab}} w_j \tag{7}$$

Calculation of the discordance interval matrix:

$$\mathrm{D} = \begin{bmatrix} - & d(1,2) & \cdots & d(1,m) \\ d(2,1) & - & \cdots & d(2,m) \\ d(3,1) & d(3,2) & - & d(3,m) \\ \cdots & \cdots & \cdots & \cdots \\ d(m,1) & d(m,2) & \cdots & - \end{bmatrix} \tag{8}$$

$$d(a,b) = \frac{\max_{j \epsilon D_{ab}} |v_{aj} - v_{bj}|}{\max_{j \epsilon 1,m} |v_{mj} - v_{nj}|} \tag{9}$$

Step 6. Determinate the concordance index matrix:

$$\begin{cases} e(a,b) = 1 \ if \ c(a,b) \geq \overline{c} \\ e(a,b) = 0 \ if \ c(a,b) < \overline{c} \end{cases} \tag{10}$$

$$\overline{c} = \sum_{a=1}^{m} \sum_{b}^{m} c(a,b)/m(m-1) \tag{11}$$

Step 7. Determinate the discordance index matrix:

$$\begin{cases} f(a,b) = 1 \ if \ d(a,b) \leq \overline{d} \\ f(a,b) = 0 \ if \ d(a,b) > \overline{d} \end{cases} \tag{12}$$

$$\overline{d} = \sum_{a=1}^{m} \sum_{b}^{m} d(a,b)/m(m-1) \quad (13)$$

Step 8. Determinate the net superior and inferior value.

Net superior value:

$$c_a = \sum_{b=1}^{n} c(a,b) - \sum_{b=1}^{n} c(b,a) \quad (14)$$

Net inferior value:

$$d_a = \sum_{b=1}^{n} d(a,b) - \sum_{b=1}^{n} d(b,a) \quad (15)$$

4. Numerical experiment

To demonstrate how the algorithm is running, let us consider the case when we would like to select a software developer. We have four assessment criteria, and these are C1 - test in databases, C2 - test in a programming language, C3 - psychological test, and C4 - interview; these tests and interviews were passed by six candidates, on the results of which, we have drawn up the following matrix, Table 1.

Table 1
Decision matrix

	C1 - test in databases	C2 - test in a programming language	C3 - psychological test	C4 - interview
Person1	90	70	85	79
Person2	87	75	96	89
Person3	80	79	74	75
Person4	75	80	92	78
Person5	82	75	69	96

Table 1 provides a decision matrix that includes evaluations of alternatives according to criteria. The pairwise comparison matrix of criteria of assessment is present in Table 2:

Table 2
Pairwise comparison matrix

	c_1	c_2	c_3	c_4
c_1	1.00	2.00	4.00	4.00
c_2	0.50	1.00	3.00	3.00
c_3	0.25	0.33	1.00	2.00
c_4	0.25	0.33	0.50	1.00

The values presented in the pairwise comparison matrix (Table 2) determine how important one criterion is over another.

Calculate the normalized pairwise comparison matrix presented in Table 3.

Table 3
Normalized pairwise comparison matrix

	c_1	c_2	c_3	c_4
c_1	0.50	0.55	0.47	0.40
c_2	0.25	0.27	0.35	0.30
c_3	0.13	0.09	0.12	0.20
c_4	0.13	0.09	0.06	0.10

Using the data in the table 3, calculate the weights of the evaluation criteria, which are given below: $c_1 = 0.48$ $c_2 = 0.29$ $c_3 = 0.13$ $c_4 = 0.09$. We should proceed with the following steps to determine whether the weights of the evaluation criteria received are acceptable. Calculate the weighted normalized decision matrix:

Table 4
Weighted normalized matrix

	c_1	c_2	c_3	c_4
c_1	0.48	0.59	0.53	0.37
c_2	0.24	0.29	0.40	0.28
c_3	0.12	0.10	0.13	0.19
c_4	0.12	0.10	0.07	0.09

Using the data in the table 4, calculate the sum of weighted values:
$c_1 = 1.97$ $c_2 = 1.21$ $c_3 = 0.54$ $c_4 = 0.38$
Calculate $\lambda_{max} = 4.077618$. Calculate Consistency Index (CI): 0.025873 Consistency ratio (CR): 0.028748. Because the CR value is less than 0.1, it is acceptable.
Let's normalize the decision matrix(which is presented in Table 1):

Table 5
Normalized decision matrix

	c_1	c_2	c_3	c_4
Person1	0.485121	0.412543	0.453425	0.421749
Person2	0.46895	0.442011	0.512104	0.475135
Person3	0.431218	0.465585	0.394747	0.400395
Person4	0.404267	0.471478	0.490766	0.41641
Person5	0.441999	0.442011	0.368075	0.512505

Let's define the weighted normalized matrix; for that, multiply the matrix given in Table 5 by the weights of the evaluation criteria.

Table 6
Weighted normalized matrix

	c_1	c_2	c_3	c_4
Person1	0.232858	0.121288	0.060306	0.039223
Person2	0.225096	0.129951	0.06811	0.044188
Person3	0.206985	0.136882	0.052501	0.037237
Person4	0.194048	0.138615	0.065272	0.038726
Person5	0.212159	0.129951	0.048954	0.047663

Let's calculate the concordance interval matrix, which is presented in the table below:

Table 7
Concordance interval matrix

	Person1	Person2	Person3	Person4	Person5
Person1	0	0.48	0.706	0.573	0.613
Person2	0.52	0	0.706	0.706	0.907
Person3	0.294	0.294	0	0.48	0.427
Person4	0.427	0.294	0.52	0	0.427
Person5	0.387	0.387	0.573	0.573	0

Let's calculate the concordance index matrix, which is presented in the table below:

Table 8
Concordance index matrix

	Person1	Person2	Person3	Person4	Person5
Person1	0	0	1	1	1
Person2	1	0	1	1	1
Person3	0	0	0	0	0
Person4	0	0	1	0	0
Person5	0	0	1	1	0

Let's calculate the discordance interval and discordance index matrices as follows:

Table 9
Discordance interval matrix

	Person1	Person2	Person3	Person4	Person5
Person1	0	1	0.602	0.446	0.418
Person2	0.895	0	0.382	0.279	0.181
Person3	1	1	0	0.987	1
Person4	1	1	1	0	1
Person5	1	1	0.664	0.90	0

Table 9 presents the discordance interval matrix:

Table 10
Discordance index matrix

	Person1	Person2	Person3	Person4	Person5
Person1	1	0	1	1	1
Person2	0	1	1	1	1
Person3	0	0	1	0	0
Person4	0	0	0	1	0
Person5	0	0	1	0	1

Table 10 presents the discordance index matrix. Let's calculate the net superior and inferior values, which are given in Table 11 below:

Table 11
Ranking

	Net superior value	Rank	Net inferior value	Rank
Person1	0.744	2	-1.42822	2
Person2	1.384	1	-2.26092	1
Person3	-1.01	5	1.387041	5
Person4	-0.664	4	1.336347	4
Person5	-0.454	3	0.965745	3

Based on the data presented in Table 11, we can rank the alternatives (human resources) to select the best one.

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4. Prototype of the decision support system

We have developed a prototype of the system's software to demonstrate the work of the algorithm of the human resource evaluation decision support system presented in the paper.

The back end of the software is written in PHP, and the front end is in Reacts. A system prototype database was developed using the MySQL database system.

Below are the main pages of the software's user interface.

The weights of the evaluation criteria are determined through the page presented below (Figure 1).

To determine the weights, as we mentioned above, we use the AHP method, for which the input data is the pairwise comparison matrix, so we must first compile the pairwise comparison matrix through the page presented in Figure 1, after which we can calculate the weights by pressing the "calculation" button.

The calculated weights are automatically reflected in the database table according to the relevant criteria. After calculating the weights, we can fill in the decision matrix.

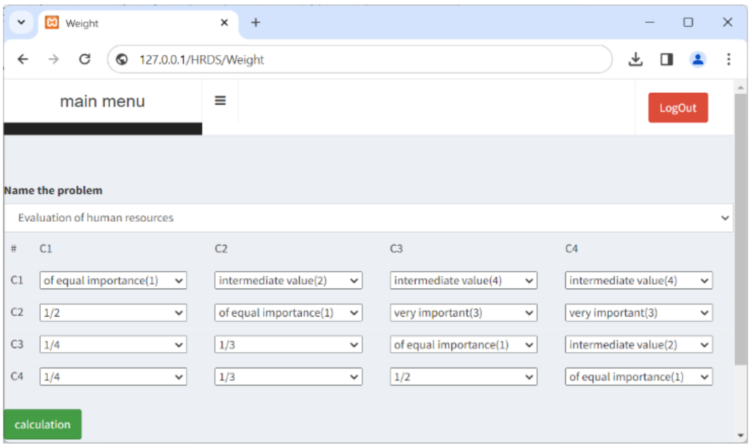

Fig 1. Calculation of weights

As mentioned, we have developed a software prototype, so in this version, we fill in the decision matrix manually to determine the experimental data to demonstrate the performance of the proposed algorithm. Below is the page for completing the decision matrix (Figure 2).

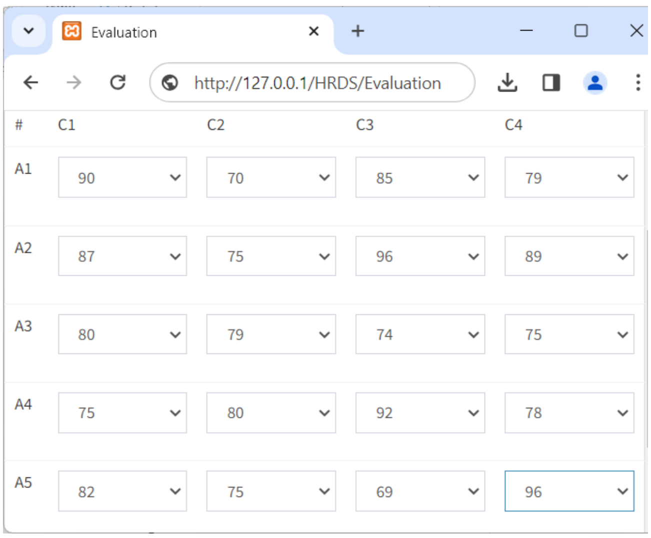

Fig 2. Decision matrix

The image (Figure 3) below shows the page through which the results of the algorithm are obtained, which is a ranked list of persons.

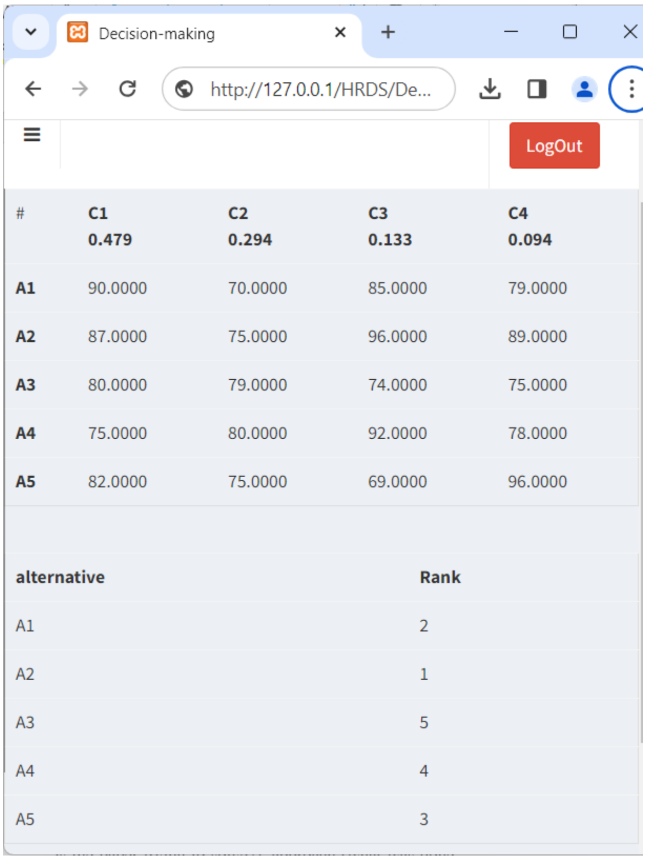

Fig 3. Results

5. Conclusions

The decision support system algorithm for human resource evaluation is adopted in the work, which offers substantial benefits for both small and large organizations by providing a structured and data-driven approach to human resource evaluation. It facilitates objective decision-making, reduces biases, and enhances the overall quality of hiring processes.

A prototype of the system software has been developed, which allows us to carry out a numerical experiment using the algorithm.

Based on the algorithm presented in the paper, we can develop a decision-making support system for human resource evaluation, which will provide significant assistance to both small and large companies at the human resources evaluation and selection stage. Although functional, the prototype of the decision support system presented in the paper does not fully describe all the complexities and nuances of human resource evaluation in different real-world situations. We are actively working to develop a decision support system based on this algorithm and implement it in pilot mode.

Conflicts of Interest

The authors declare no conflicts of interest.

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