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# MULTIDIMENSIONAL PERSONNEL SELECTION THROUGH COMBINATION OF TOPSIS AND HUNGARY ASSIGNMENT ALGORITHM

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Abstract
This paper proposes an effective solution based on combined TOPSIS and Hungary assignment approach to help companies that need to assign personnel to different departments. An extension of TOPSIS (technique for order performance by similarity to ideal solution) combined by Hungary assignment algorithm is represented for this purpose. According to decrease resistance of employee opposite of recruitment of new employee, Decision criteria are obtained from the nominal group technique (NGT) and managers of each departments has been involved in decision making process. In the presented solution, managers of four departments have been involved in evaluating four candidates for their department and data is analyzed by TOPSIS and at the end, an effective fit between personnel and their corresponding department is presented.

Keywords
TOPSIS, Hungary assignment, personnel selection, NGT.

## Introduction

Industries that can compete in today's competitive market will be those that can win in global competition, not those that require protection from competitive forces. As a result, businesses irrespective of size have to be competitive and stay competitive [1].

As globalization intensifies, human capital becomes a critical element for the success of firms [2]. In addition, successful recruitment is also crucial for a nation's economic growth due to the shortage in qualifies labor force in many countries [3].

Recruitment activities are processes aimed at singling out applicants with the required qualifications and keeping them interested in the organization so that they will accept a job offer when it is extended. Substantial research has been conducted on recruitment due to its critical role in bringing human capital into organizations [4].

Individual assessment refers to one-on-one valuations on the basis of a wide range of cognitive and non cognitive measures that are integrated by the assessor, often resulting in a recommendation rather than a selection decision or prediction of a specific level of job performance [5].

In a research occurred in 2013, actual application of academic of staff selection using the opinion of experts applied into a model of group decision - making called the Fuzzy ELECTRE method. There were ten qualitative criteria for selecting the best candidate amongst five prospective applications [6].

Ertugrul developed a fuzzy multi-criteria decision making framework based on the concepts of ideal and anti-ideal solution for selecting the most appropriate candidate from the short-listed applicants. The method enables users to incorporate data in the forms of linguistic variables [7].

Wang developed an approach based on the TOPSIS, to help the decision makers choose optimal R&D personnel in an uncertain environment. In his work, at first, the rating of each alternative and the weight of each criterion were described by linguistic terms which can be expressed in interval grey numbers, then, a relative closeness is defined to determine the ranking order of all alternatives by calculating the grey relational grade (GRG) of each alternative to the ideal and negative ideal solution simultaneously [8].

Selecting personnel for organization is dependent on the company's desired purposes, the limited resources, and even the company's preferences. This problem is affected by many factors which may be in conflict and adhere with imprecision and uncertain data. Hence the personnel selection is a kind of Multi-criteria decision-making (MCDM) problem, which requires MCDM methods for an effective problem solving. It is clear that the selection among candidates is a difficult issue which has quantitative and qualitative aspects. Involving several people from functional areas in personnel selection process increased the complexity of this process.

The most important issue in the process of personnel selection is developing an effective method to select the best one. As mentioned above, this problem is a group decision making process under multiple criteria. Although the successful implementation of personnel selection program is vital important, it is necessary to utilize meditating entities as a consultant to successful implementation of this program, insufficient attention has been paid by researchers to the support them in this field. In this paper, using the concept of linguistic values, a systematic decision process for selecting personnel is proposed. The proposed method is based on TOPSIS method by a relationship with Hungary assignment algorithm. The decision criteria are obtained from the nominal group technique (NGT). The rest of the paper is structured as follows: In the next section a brief overview of MCDM, TOPSIS method, NGT and Hungary assignment method is presented. Section 3 concentrates on the proposed model with an illustrative example. In the final section some conclusions are drawn.

## Literature review

In this paper, a systematic decision process for selecting appropriate personnel is proposed. The proposed method is based on TOPSIS method and utilized Hungary assignment algorithm. The nominal group technique (NGT) has been used to obtain the decision criteria. Here is some definition to show the rest of paper's structure as follows: In the next section a brief overview of MCDM, TOPSIS method, Nominal Group Technique, and concepts of Hungary assignment algorithm are presented. Section three focuses on the proposed model. According to illustrating the application of the proposed method, a real case study is presented in this Section too. In the final section some conclusions are drawn.

### Multi-criteria decision making methods

Multi-criteria decision-making (MCDM) refers to screening, prioritizing, ranking, or selecting a set of alternatives and options under usually independent, incommensurate, or conflicting attributes [9]. Over the years, some MCDM methods have been proposed. The methods differ in many areas, theoretical background, type of questions and the type of results given [10]. Some methods have been created particularly for one specific problem and are not useful for other problems. Other methods are more universal and many of them have attained popularity in various areas. The main idea for all methods is to create a more formalized and better informed decision-making process [11]. There are many possible ways to classify the existing MCDM methods. Belton and Stewart classified them in 3 broad categories: value measurement model such as Multi-Attribute Utility Theory (MAUT) and Analytical Hierarchy process (AHP); outranking models such as Elimination and Et Choice Translating Reality (ELECTRE) and Preference Ranking Organization Method for Enrichment Evaluation (PROMETHEE) and at last, goal aspiration and reference level models such as Technique for Order Preference by Similarity to Ideal Solution [12].

### TOPSIS

The TOPSIS method ranks the alternatives according to their distances from the ideal and the negative ideal solution, i.e. the best alternative has simultaneously the shortest distance from the ideal solution and the farthest distance from the negative ideal solution [13]. The ideal solution is identified with a hypothetical alternative that has the best values for all considered criteria whereas the negative ideal solution is identified with a hypothetical alternative that has the worst criteria values. In practice, TOPSIS has been successfully applied to solve selection/evaluation problems with a finite number of alternatives because it is intuitive and easy to understand and implement. Furthermore, TOPSIS has a sound logic that represents the rationale of human choice and has been proved to be one of the best methods in addressing the issue of rank reversal [14, 15].

An extension of TOPSIS has been used for selecting knowledge management strategies in 2013. In this research, data has been normalized in statistical form [16].

In this paper, we extend TOPSIS approach proposed by [13] for consultant selection problem because of following reasons and advantages [17]:

- A sound logic that represents the rational of human choice.
- A scalar value that accounts for both the best and worst alternative simultaneously.
- A simple computation process that can be easily programmed into a spreadsheet.
- The performance measures of all alternatives on attributes can be visualized on a polyhedron, at least for any two dimensions.

### Nominal Group Technique

There are a number of "group-based" research techniques available to determine the views or perceptions of individuals in relation to specific topics. The purposes of such work is to increase the depth and scope of discussion, ensure wide coverage of ideas, and involve group members in selecting priorities and to seek agreement or consensus on the topic in question, Nominal Group Technique and Delphi, Focus Groups and Brainstorming are formal and more useful group management techniques. When comparing the NGT with other group processes the NGT has a number of advantages over other group processes [18]. The NGT approach was described in the 1960's. Since that time it has been applied in a wide range of fields including education, health, social service, industry, and government organizations [19]. NGT forces everyone to participate and no dominant person is allowed to come out and control the proceedings. In NGT, all ideas have equal stature and will be judged impartially by the group [20]. The procedure of NGT can be briefed as the following four steps [21]:

1. Silent generation of ideas in writing.
2. Round-robin recording of ideas.
3. Serial discussion of the list of ideas.
4. Voting.

### Hungary assignment

Harold W. Kuhn, in his celebrated paper entitled The Hungarian Method for the assignment problem, described an algorithm for constructing a maximum weight perfect matching in a bipartite graph [22].

In his delightful reminiscences, Kuhn explained how the works of two Hungarian mathematicians, D. Konig and E. Egervary, had contributed to the invention of his algorithm, the reason why he named it the Hungarian Method. (For citations from Kuhn's account as well as for other invaluable historical notes on the subject, see A. Schrijver's monumental book [23].

The main idea of Kuhn's algorithm is that the two separate parts in Egervary's proof (computing a de?cient set and revising the current $\pi$) are combined into one [24].

This method has been used when our purpose is to assign some things to some state. For example, when we want to assign some person to some jobs, it's useful to help this method. It's important to alert that before using this algorithm, it's necessary to create standard situation.

In traditional methods of assign, some things become assigned to some segment by considering only one criterion, but in our method assignment occurs by considering some criteria.

## Combination of TOPSIS and Hungary

A systematic approach to extend the TOPSIS combined by Hungary assignment is proposed in this section. This method is so suitable for solving the group decision-making problem in scope of delegation of authority in an organization. In this paper, the importance weights of various criteria and the ratings of qualitative criteria are considered as linguistic variables.

On the whole, the steps of an algorithm of the multi-person multi criteria decision making combined by Hungary algorithm is given in the following as a numerical example. This algorithm includes two fundamental phase: applying TOPSIS as phase one and applying Hungary assignment algorithm as phase two. Here are the steps of first phase as bellow:

### Applying TOPSIS

In this part, we solve four separate decision making problem four each department of organization and evaluate four candidates by five criteria for four department separately. Here are the phases of applying TOPSIS for four departments of organization.

#### A) Nominate the problems objectives:

Decision making is the process of defining the decision goals, gathering relevant criteria and possible alternatives, evaluating the alternatives for advantages and disadvantages, and selecting the optimal alternative [25]. In this phase, the objectives of our decision should become evident. One of the important differences between our method and the other decision making problems is in its goal. As mentioned, we want to assign some persons to some departments of an organization. So our objective is assigning appropriate persons to departments of Knowledge, Quality, Marketing and Finance. We name these departments as $D = \{D_1, D_2, D_3, D_4\}$ and these persons as $P = \{P_1, P_2, P_3, P_4\}$.

**B) Identify the evaluation criteria, weights, and the appropriate linguistic variables:**

In selecting manager for each department of an organization, it is critical to form a team and involve several experts from different departments to create the best adaptability between organization and proposed employees for departments [11]. It's very important to make an Effective and efficient communication between different experts because the better the parties are informed about employees selection, the higher the probability that the parties will be committed to supporting this selection The more different perspectives are initially taken into account, and the greater the complexity of convergence, the smaller the chances of addressing the wrong problem and reaching an inadequate solution [26]. The objectives of selection, the scope of selection and possible alternatives should become defined as well as possible. According to this goal, the NGT group formed and after some group meeting, 4 departments, 5 criteria for evaluating employees, and 4 persons as alternatives to delegate authority of those departments to them were selected. The selected departments are Marketing, Knowledge, Quality, and Finance. We named the persons for undertaking the different department's responsibility will as $A_i = \{A_1, A_2, ..., A_m\}$. After the NGT technique is employed, the committee identifies five criteria as the same as TQM consultant selection's criteria [11]. These criteria have been represented as follows:

1. Relevant experience (similar projects and firms).
2. Knowledge of business (strategies, process, markets).
3. Technical skills (people, system, specific abilities).
4. Management skills (organization, economic Stability, acceptable insurance, certificates).
5. Implementation cost.

To show the difference between criteria's important, NGT choose weight of each criteria too and called them $W = \{w_1, w_2, w_3, w_4\}$.

**C) Create the decision matrix**

The employee selection problem can be expressed in the matrix format for 4 alternatives and 5 criteria in order to evaluating them. The difference between our decision matrix in this article and the common decision matrixes is in the number of tables. As mentioned in last paragraph, we were to evaluate 4 person's abilities and assign them to the most suitable department according to their competence. Solving this problem needed to two separate methods. In the first phase we established 4 decision matrixes. Each of them belongs to one department. The real data that has been gathered for j'th department has been called $r_j$, $r_j = \{r_1, r_2, r_3, r_4\}$. In other word, in each of those matrixes we evaluated selected employee for each of those department. These matrixes filled with data that has been collected from the expert managers of organization in strategic management team. For each of those matrixes, the data has been gathered and analyzed and at the end, the final matrixes fulfilled with the final results. 4 matrixes of this phase have been showed in Table 1. In this step when the NGT technique is applied, we will have a set of 5 criteria, $C = \{C_1, C_2, C_3, C_4, C_5\}$ defined and described; with which employee performance is measured. Criteria can be classified into two types: benefit criteria and cost criteria.

Table 1

Decision matrixes for departments of enterprise.

| $\mathbf{r_1}$ | $\mathbf{C_1}$ | $\mathbf{C_2}$ | $\mathbf{C_3}$ | $\mathbf{C_4}$ | $\mathbf{C_5}$ |
|---|---|---|---|---|---|
| $A_1$ | 7 | 5 | 2 | 4 | 6 |
| $A_2$ | 6 | 4 | 1 | 6 | 4 |
| $A_3$ | 2 | 7 | 4 | 3 | 4 |
| $A_4$ | 2 | 7 | 6 | 4 | 7 |
| $\mathbf{r_2}$ | $\mathbf{C_1}$ | $\mathbf{C_2}$ | $\mathbf{C_3}$ | $\mathbf{C_4}$ | $\mathbf{C_5}$ |
| $A_1$ | 4 | 5 | 2 | 6 | 7 |
| $A_2$ | 7 | 2 | 3 | 4 | 4 |
| $A_3$ | 5 | 6 | 5 | 5 | 3 |
| $A_4$ | 2 | 7 | 6 | 6 | 4 |
| $\mathbf{r_3}$ | $\mathbf{C_1}$ | $\mathbf{C_2}$ | $\mathbf{C_3}$ | $\mathbf{C_4}$ | $\mathbf{C_5}$ |
| $A_1$ | 5 | 4 | 7 | 3 | 5 |
| $A_2$ | 7 | 7 | 7 | 1 | 7 |
| $A_3$ | 2 | 6 | 5 | 6 | 5 |
| $A_4$ | 1 | 3 | 7 | 2 | 4 |
| $\mathbf{r_4}$ | $\mathbf{C_1}$ | $\mathbf{C_2}$ | $\mathbf{C_3}$ | $\mathbf{C_4}$ | $\mathbf{C_5}$ |
| $A_1$ | 7 | 1 | 1 | 2 | 4 |
| $A_2$ | 7 | 4 | 3 | 5 | 6 |
| $A_3$ | 1 | 7 | 5 | 6 | 4 |
| $A_4$ | 5 | 5 | 3 | 7 | 5 |

### D) Calculate the normalized decision matrix

Normalization is an operation to make different data conform to or reduced to a norm or standard. The values of each element in a normalized matrix are all between 0 and 1. We do this operation to make alternatives comparable. Yoon and Hwang partition attributes into three groups: benefit attributes, cost attributes, and non-monotonic attributes [2]. A few common normalization methods are organized in Table 2. These are classified as vector normalization, linear normalization, and non-monotonic normalization to fit real-world situations under different circumstances. Additionally, three forms for linear normalization are listed here.

Table 2
Common methods of normalization for TOPSIS.

| |
|---|
| **Vector normalization (1)** |
| $r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{j=1}^{m} x_{ij}^2}}; \quad j = 1,2,...,m; \quad i = 1,2,...,n$ |
| **Vector normalization (2)** |
| $r_{ij} = \frac{x_{ij}}{\sum_{j=1}^{m} x_{ij}}; \quad j = 1,2,...,m; \quad i = 1,2,...,n$ |
| **Linear normalization** |
| $r_{ij} = \frac{x_{ij}}{x_j^*}; \quad j = 1,2,...,m; \quad i = 1,2,...,n; \quad x_j^* = \max_i(x_{ij})$ for benefit attribut |
| **Fuzzy normalization** |
| $r_{ij} = \frac{\widetilde{x}_j}{x_{ij}}; \quad j = 1,2,...,m; \quad i = 1,2,...,n; \quad \widetilde{x}_j = \min_i(x_{ij})$ for cost attribut |
| $r_{ij} = \frac{x_{ij} - \widetilde{x}_j}{x_j^* - \widetilde{x}_{ij}}; \quad j = 1,2,...,m; \quad i = 1,2,...,n;$ for benefit attribut |
| $r_{ij} = \frac{x_j^* - x_{ij}}{x_j^* - \widetilde{x}_j}; \quad j = 1,2,...,m; \quad i = 1,2,...,n;$ for cost attribut |

The normalization of the decision matrix in this article is done using the following transformation:

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

$$j = 1,2,...,m; \qquad i = 1,2,...,n.$$

### E) Create weighted normalized matrix

Multiply the columns of normalized decision matrixes by the associated weights from NGT mentioned in previous paragraph. $w_j$ represents the weight of the $j_{th}$ criteria and has been shown in Table 3.

Table 3
Weight of attributes.

| | $C_1$ | $C_2$ | $C_3$ | $C_4$ | $C_5$ |
|---|---|---|---|---|---|
| Weight | 0.174 | 0.304 | 0.174 | 0.217 | 0.130 |

The weighted normalized decision matrix is obtained as:

$$V_{ij} = n_{ij} \cdot w_j; \quad j = 1,2,...,m; \quad i = 1,2,...,n, \tag{2}$$

where $n_{ij}$is the normalized value, $w_j$ is the weight of each criteria and $v_{ij}$ is the weighted and normalized value. Table 4 shows Weighted and normalized decision matrix.

Table 4
Decision matrixes for departments of enterprise.

| $\mathbf{V}_1$ | $\mathbf{C}_1$ | $\mathbf{C}_2$ | $\mathbf{C}_3$ | $\mathbf{C}_4$ | $\mathbf{C}_5$ |
|---|---|---|---|---|---|
| $A_1$ | 0.126 | 0.129 | 0.046 | 0.099 | 0.072 |
| $A_2$ | 0.108 | 0.103 | 0.023 | 0.149 | 0.048 |
| $A_3$ | 0.036 | 0.181 | 0.092 | 0.074 | 0.048 |
| $A_4$ | 0.036 | 0.181 | 0.138 | 0.099 | 0.084 |
| $\mathbf{V}_2$ | $\mathbf{C}_1$ | $\mathbf{C}_2$ | $\mathbf{C}_3$ | $\mathbf{C}_4$ | $\mathbf{C}_5$ |
| $A_1$ | 0.138 | 0.022 | 0.022 | 0.161 | 0.176 |
| $A_2$ | 0.241 | 0.009 | 0.033 | 0.108 | 0.100 |
| $A_3$ | 0.172 | 0.027 | 0.055 | 0.134 | 0.075 |
| $A_4$ | 0.069 | 0.031 | 0.066 | 0.161 | 0.100 |
| $\mathbf{V}_3$ | $\mathbf{C}_1$ | $\mathbf{C}_2$ | $\mathbf{C}_3$ | $\mathbf{C}_4$ | $\mathbf{C}_5$ |
| $A_1$ | 0.179 | 0.087 | 0.073 | 0.039 | 0.106 |
| $A_2$ | 0.251 | 0.152 | 0.073 | 0.013 | 0.148 |
| $A_3$ | 0.072 | 0.130 | 0.052 | 0.077 | 0.106 |
| $A_4$ | 0.036 | 0.065 | 0.073 | 0.026 | 0.085 |
| $\mathbf{V}_4$ | $\mathbf{C}_1$ | $\mathbf{C}_2$ | $\mathbf{C}_3$ | $\mathbf{C}_4$ | $\mathbf{C}_5$ |
| $A_1$ | 0.220 | 0.010 | 0.023 | 0.028 | 0.104 |
| $A_2$ | 0.220 | 0.042 | 0.068 | 0.070 | 0.156 |
| $A_3$ | 0.031 | 0.073 | 0.113 | 0.084 | 0.104 |
| $A_4$ | 0.157 | 0.052 | 0.068 | 0.098 | 0.130 |

### F) Determine the ideal and negative ideal solution from the matrixes:

The ideal values set and the nadir values set of each matrix are determined as follows:

$$A^+ = \{v_1^+, v_2^+, ..., v_n^+\} = \{(\max v_{ij} | j \in J).(\min v_{ij} | j \in J') | i = 1,2,...,m\}, \tag{3}$$

$$A^- = \{v_1^-, v_2^-, ..., v_n^-\} = \{(\min v_{ij} | j \in J).(\max v_{ij} | j \in J') | i = 1,2,...,m\} \tag{4}$$

where $J$ is the index set of benefit criteria and $J'$ is the index set of cost criteria.

### G) Measure distances from the ideal and nadir solutions

The two Euclidean distances for each alternative in each matrix are calculated as:

$$s_i^+ = \left\{\sum (v_{ij} - v_j^+)^2\right\}^{0.5}; \qquad j = 1, 2, ..., m; \qquad i = 1, 2, ..., n, \tag{5}$$

$$s_i^- = \left\{\sum (v_{ij} - v_j^-)^2\right\}^{0.5}; \qquad j = 1, 2, ..., m; \qquad i = 1, 2, ..., n. \tag{6}$$

### H) Measure distances from the ideal and nadir solutions

Calculate the relative closeness to the ideal solution. The relative closeness to the ideal solution can be determined as:

$$c_i = \frac{s_i^-}{s_i^- + s_i^+}; \quad i = 1, 2, ..., n; \quad 0 \le c_i \le 1. \tag{7}$$

We calculated the content of ideal and nadir ideal and distances of each alternative from the ideal and nadir for our problem in each department and also Calculate the relative closeness to the ideal solution in four matrixes and represent results in Table 5.

Table 5
Relative closeness to the ideal solution.

| Department 1 | | | | Department 1 | | | |
|---|---|---|---|---|---|---|---|
| | **S$^+$** | **S$^-$** | **C** | | **S$^+$** | **S$^-$** | **C** |
| $A_1$ | 0.10 | 0.12 | 0.46 | $A_1$ | 0.15 | 0.11 | 0.59 |
| $A_2$ | 0.11 | 0.14 | 0.44 | $A_2$ | 0.23 | 0.09 | 0.72 |
| $A_3$ | 0.11 | 0.12 | 0.47 | $A_3$ | 0.18 | 0.18 | 0.37 |
| $A_4$ | 0.14 | 0.11 | 0.56 | $A_4$ | 0.07 | 0.24 | 0.22 |
| **Department 2** | | | | **Department 1** | | | |
| | **S$^+$** | **S$^-$** | **C** | | **S$^+$** | **S$^-$** | **C** |
| $A_1$ | 0.09 | 0.15 | 0.37 | $A_1$ | 0.19 | 0.13 | 0.60 |
| $A_2$ | 0.19 | 0.07 | 0.72 | $A_2$ | 0.20 | 0.08 | 0.71 |
| $A_3$ | 0.15 | 0.07 | 0.67 | $A_3$ | 0.13 | 0.19 | 0.41 |
| $A_4$ | 0.10 | 0.17 | 0.38 | $A_4$ | 0.16 | 0.08 | 0.65 |

## Hungary assignment algorithm

After evaluating four candidates by five criteria for four departments, we have four sets of $C_{ij}$ as distances from the ideal and nadir solutions for each department. Now it's time to assign four compared person to four departments by using Hungary assignment algorithm. Here are steps of this algorithm based on the consequences of last part:

### A) Assignment matrix:

Assignment matrix is a matrix with equal rows and columns. In this article we want to assign four persons to four departments. Rows of this matrix are candidate person called as $A_j = \{A_1, A_2, A_3, A_4\}$ and column of this matrix are different departments called as $D_j = \{D_1, D_2, D_3, D_4\}$ and value of each sells in this matrix is quantity of $C_{ij}$ parameter, calculated in past part. Assignment matrix has been showed in Table 6.

Table 6
Assignment matrix (Cij).

| | $D_1$ | D2 | $D_3$ | $D_4$ |
|---|---|---|---|---|
| $A_1$ | 0.457 | 0.369 | 0.592 | 0.600 |
| $A_2$ | 0.439 | 0.724 | 0.720 | 0.713 |
| $A_3$ | 0.467 | 0.669 | 0.369 | 0.415 |
| $A_4$ | 0.564 | 0.377 | 0.223 | 0.653 |

### B) Standardize values of matrix

Hungary assignment works in a standard term. The value of assignment matrix must have negative nature; this is one of the standardization terms of this method. As we put value of $C_{ij}$ parameter in assignment matrix in past part, and as this parameter has positive nature, we should decrease each sell's value from maximum value of matrix to standardize the matrix. Table 7 shows standard assignment matrix.

Table 7
Standard assignment matrix.

| | $D_1$ | $D_2$ | $D_3$ | $D_4$ |
|---|---|---|---|---|
| $A_1$ | 0.267 | 0.355 | 0.132 | 0.125 |
| $A_2$ | 0.285 | 0.000 | 0.004 | 0.011 |
| $A_3$ | 0.258 | 0.055 | 0.355 | 0.309 |
| $A_4$ | 0.160 | 0.348 | 0.501 | 0.071 |

### C) Create reduced cost matrix

Hungary assignment is based on reduced cost matrix, according to achieve this purpose, at first we should decrease minimum of each rows from the parameters of that row as bellow formula:

$$c'_{ij} = c_{ij} - \min c_i, \qquad j = 1, 2, 3, 4, \qquad i = 1, 2, 3, 4,$$

where $c_{ij}$ is the value of each parameter and after decreasing the minimum value of the row, $c'_{ij}$ which shows reduced cost of each row, will be obtained.

The next step to create reduced cost matrix is decrease minimum of each column which changed in past step from the parameters of that column as bellow formula:

$$c''_{ij} = c'_{ij} - \min c_j,$$

$$j = 1, 2, 3, 4, \quad i = 1, 2, 3, 4,$$

where $c'_{ij}$ is the reduced cost of parameters in each row and after decreasing the minimum value of the column, $c''_{ij}$ which shows final reduced cost of each parameter, will be obtained.

Table 8 shows the final reduced cost matrix.

Table 8
Reduced cost matrix.

| | $D_1$ | $D_2$ | $D_3$ | $D_4$ |
|---|---|---|---|---|
| $A_1$ | 0.053 | 0.230 | 0.003 | 0.000 |
| $A_2$ | 0.196 | 0.000 | 0.000 | 0.011 |
| $A_3$ | 0.113 | 0.000 | 0.296 | 0.254 |
| $A_4$ | 0.000 | 0.277 | 0.426 | 0.000 |

### D) Testing Optimality of matrix

After creation of reduced cost matrix, it's necessary to test optimality of matrix. We should see how many vertically and horizontal line is minimal necessary to cover all parameter with zero value. If the number of these lines is equal to number of matrix's dimension, we should choose one row or column with a just one zero value on it and eliminate row and column that zero value is on their clash. This method will become continued so that every rows and column became eliminated. In such situation, location of this zero value is the best point for assign. We should these steps on our matrix. Here is optimum matrix with line around optimum point in Table 9.

Table 9
Optimum matrix.

| | $D_1$ | $D_2$ | $D_3$ | $D_4$ |
|---|---|---|---|---|
| $A_1$ | 0.053 | 0.230 | 0.003 | 0.000 |
| $A_2$ | 0.196 | 0.000 | 0.000 | 0.011 |
| $A_3$ | 0.113 | 0.000 | 0.296 | 0.254 |
| $A_4$ | 0.000 | 0.277 | 0.426 | 0.000 |

### E) Assign best alternative

As see in Table 9, the clash point of first row and forth column, second row and third column, third row and second column and finally forth row and first column have zero value. In other word, the best assign of four persons to four departments based on five different criteria, is shown in Table 10. So, the final assignment is shown in bellow table.

Table 10
Consequent matrix.

| Person | Management |
|---|---|
| Person 1 | Financial |
| Person 2 | Quality |
| Person 3 | Knowledge |
| Person 4 | Marketing |

## Conclusion and future research challenges

In this paper, a new technique, based on TOPSIS for multidimensional decision making problems is considered. The important application of this method can be in delegation in an organization.

However, the personnel selection in an organization is a kind of MCDM problem, which requires considering a large number of complex factors as multiple evaluation criteria. Although numerous creditable works are devoted to the study of how to select appropriate personnel for different department, few of those have provided methods which can systematically evaluate and model complex factors of the personnel selection.

Dealing with the MCDM problem of this personnel selection, it is better to employ MCDM methods for reaching an effective problem-solving. The TOPSIS not only can be used as a way to handle the inner dependences within a set of criteria, but also can produce more valuable information for making decisions. Hence, this paper proposed a solution based on a combined Hungary assignment and TOPSIS approach to help companies that need to evaluate and select personnel for different departments.

It's important to note that selecting appropriate personnel for different departments of an organization usually have a degree of resistance by that department. For decreasing this resistance, we use NGT for identifying evaluation's criteria and also use an extension of TOPSIS for group decision making and want every managers of each departments to evaluate 4 personnel by 5 criteria according to their own viewpoints for their department. Finally we put consequences of these judgments in assignment matrix and assign most appropriate personnel to most suitable department by using principles of Hungary assignment algorithm.

The results of this study show that it's better to assign person.1 to department.1, person.2 to department.2, person.3 to department.3, and person.4 to department.4. Additionally, this study has contributed to extend practical applications of both TOPSIS and Hungary assignment algorithm in personnel selection field.

Here are the advantages of this method in comparison of the older methods:

- Decreasing personnel resistance against especially department's managers against employee utilization because of usage of NGT technique.
- Increasing the probability of adaptation between employees and their job because of multidimensional selection by different opinion of different managers.
- Creation of a good relation between manager and his new employee because of multidimensional selection.
- High acceptance of new employees by the other departments because of their recognitions about them.
- Increasing the level of job satisfaction because of good adaptation between employees and their jobs.
- Increasing the level of transparency of job interview meetings and preventing of bad considerations.

As a future step to this paper, we can partner all personnel of specific departments in decision making. For this purpose we can want middle personnel of each department to evaluate proposed candidates for their department. This action will result in decreasing potential resistance of personnel after Recruitment of new employee and increasing effectiveness of this personnel assignment. As another future step to this paper, we can use AHP or entropy method for assigning weight to each criterion for each department, because it's probable that importance of one criterion in front the others be different in different departments.

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