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PERSONNEL SELECTION FOR PROMOTION USING AN INTEGRATED FUZZY ANALYTIC HIERARCHY PROCESS-GREY RELATIONAL ANALYSIS METHODOLOGY: A REAL CASE STUDY

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ABSTRACT

The basic idea of personnel selection is to choose the best candidate for a job. Personnel selection is crucial in human resources management and also it is very important for both academicians and industrialists. Personnel selection can be a solution to a Multi Criteria Decision Making (MCDM) problem.

The aim of this paper is to determine the best personnel by integrating Fuzzy Analytic Hierarchy Process (FAHP) and Grey Relational Analysis (GRA) methodology. FAHP is used to determine the importance weights of personnel (17 alternatives) according to personnel selection criteria (22 subcriteria are categorized under 5 main criteria). Then, obtained fuzzy importance weights are defuzzified by centroid method. After that, defuzzified importance weights of personnel according to personnel selection criteria are integrated with a GRA model to prioritize the personnel alternatives. For a case study in Turkey, the ranking of the alternatives is calculated using the integrated FAHP-GRA model, and the best-performing personnel is selected for promotion. According to this methodology, managers/human resources department can easily predict how they can evaluate and promote employees.

The proposed methodology requires less data and analyzes many factors by removing complexity of statistics methods in the literature. The main contribution of this study is to reduce data for a preference matrix using the integrated methodology. As a result, the number of transactions decrease. To the authors’ knowledge, this will be the first study which integrates Fuzzy Analytic Hierarchy Process (FAHP) and Grey Relational Analysis (GRA) methodologies for human resources in the area of industrial engineering.

Keywords: Personnel selection, Personnel selection criteria, Multi criteria decision making (MCDM), Fuzzy analytic hierarchy process (FAHP), Grey relational analysis (GRA)

1. INTRODUCTION AND LITERATURE REVIEW

One of the most important factor in human resources management is personnel selection. Personnel Selection (PS) results from the need for employees and aims to make a proper choice for the position. In other words, Personnel Selection is a process that continues until the approriate person is chosen. Personnel selection can be described as employing somebody for a particular position. In order to be able to complete the selection process, the number of candidates should be more than the number of needed employees. After these phases, one of the applicants is selected according to criteria the organization described. Choosing the proper employee for the position is one of the most preliminary factor that can determine the success of the company.

The advantages of personnel selection are to reduce the discrimination and to prevent the selecting "inadequate" employees for a job. Therefore, organizations don’t have to spend time and pay training costs required to educate and develop incorrectly placed employees.

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Selecting or prioritizing alternatives from a set of available alternatives with respect to multiple criteria is often referred as multi-criteria decision-making (MCDM) [1]. Multi Criteria Decision Making (MCDM) can be used for personnel selection process. Some of the methods applied in this area are the Analytic Hierarchy Process (AHP), Analytic Network Process (ANP), Technique for Order Preference by Similarity to Ideal Solutions (TOPSIS), Fuzzy Set Theory, Expert Systems (ES), their hybrids, etc.

The purpose of this current study is to determine the best personnel to be promoted in a firm according to the prioritized personnel selection criteria defined by us. The personnel selection criteria are used from our recent research [2]. In our recent research we aimed to determine personnel selection criteria and to prioritize these criteria by using one of the Multi Criteria Decision Making (MCDM) techniques, which is Consistent Fuzzy Preference Relations (CFPR) [2]. However, CFPR method can only determine personnel selection criteria and prioritize these criteria; it cannot determine the best personnel alternative. So, the personnel selection problem is improved for this study and two MCDM methods are integrated to select the best personnel. These methods are Fuzzy Analytic Hierarchy Process (FAHP) and Grey Relational Analysis (GRA). Firstly, the importance weights of the personnel (17 alternatives) according to personnel selection criteria (22 subcriteria of 5 main criteria) [2] are prioritized using FAHP methodology. Then centroid defuzzification method is used for fuzzy importance weights. After that, GRA methodology is used for ranking of the alternatives. It cannot be found any study integrating these two techniques in personnel selection in the literature.

Many studies have been done about personnel selection by using MCDM methods in the literature [3-15]. In the literature, GRA and other methodologies integrated with GRA have been studied extensively. Lin et al. [16] reported the use of the grey relational analysis based on an orthogonal array and fuzzy-based Taguchi method for optimizing the multi-response process. Chang et al. [17] used Grey relational grade deduced by Grey theory [18] to establish a complete and accurate evaluation model for determining who the best all-around athlete among all contestants is. Wu [19] used GRA method in Multiple Attribute Decision Making (MADM) problems. Yang and Chen [20] proposed an integrated model by combining the AHP and GRA into a single evaluation model for supplier selection in an outsourcing manufacturing organization. Kuo et al. [21] proposed a MADM method, GRA, for solving facility layout and dispatching rules selection problem. Hou [22] established an optimization model based on the basic ideal of traditional GRA method in order to get the weight vector of the attribute. Then, based on the traditional GRA method, calculation steps for solving intuitionistic fuzzy multiple attribute decision-making problems with completely known weight information were given.

Zhang and Liu [23] developed an intuitionistic fuzzy multi-criteria group decision making method with GRA for solving the personnel selection problem. Pitchipoo et al. [24] proposed a grey based decision making approach to deal with the supplier evaluation and selection in a process industry. Pramanik and Mukhopadhyaya [25] developed an intuitionistic fuzzy multi criteria group making method with GRA for teacher selection in higher education. Sofyalioglu and Ozturk [26] compared three different methods for prioritizing failure modes in a design FMEA study. These methods were traditional approach, Grey Relational Analysis (GRA- under the assumption of risk factors having equal weights) and integration of GRA and FAHP. Goyal and Grover [27] proposed a MADM method, Fuzzy Grey Relational Analysis (FGRA), for Advanced Manufacturing System (AMS) selection.

Rajesh and Ravi [28] used GRA based on linguistic assessment of supplier rating and attribute weightings for prioritizing supplier selection. Rajyalakshmi and Ramaiah [29] examined process parameters optimization of multiple response characteristics of WEDM on Inconel-825 super alloy using FGRA. Kundakci [30] proposed a scientific MCDM method using GRA for employee selection. Sari et al. [31] developed an alternative solution strategy for supplier selection problem under uncertain conditions by GRA. Pakkar [32] proposed an integration of the AHP and data envelopment analysis (DEA) methods in a multi-featured GRA methodology in which the attribute weights are completely unknown and the attribute values take the form of fuzzy numbers. Kabak and Dagdeviren [33] proposed a hybrid approach which combines ANP and GRA. To identify weights of the selection criteria and to analyze the machine selection problem, the ANP is used whilst the GRA is used for ranking.

The FAHP technique can be viewed as an advanced analytic method developed from the traditional AHP. Buckley extended Saaty's AHP to the case where the evaluators are allowed to employ fuzzy ratios in place of exact ratios to handle the difficulty for people to assign exact ratios when comparing two criteria and derive the fuzzy weights of criteria by geometric mean method [34].

FAHP approach can be used for the evaluation and ranking of alternatives [35-37]. Buyukozkan et al. [38] proposed FAHP method to evaluate e-logistics-based strategic alliance partners. Cascales and Lamata [39] proposed FAHP for management maintenance processes where only linguistic information was available. Alias et al. [40] used FAHP technique to rank alternatives to find the most reasonable and efficient use of river system.

FAHP is used also for personnel selection in the literature as an application area. Mikhailov [41] proposed a new fuzzy programming method to partnership selection problem in the basic framework of the AHP. Huang et al. [42] combined FAHP, Fuzzy Neural Networks, and Simple Additive Weighting (SAW) method to construct a new model for evaluation of managerial talent, and to develop a decision support system in human resource selection. Gungor et al. [43] proposed a personnel selection system based on FAHP to evaluate the best adequate personnel. Celik et al. [44] proposed Fuzzy Integrated Multi-stages Evaluation Model (FIMEM) for academic personnel selection. The FIMEM consisted of FAHP and Fuzzy TOPSIS. Chen [45] constructed fuzzy multiple criteria model by FAHP for employee recruitment. Sun [46] developed an evaluation model by integrating FAHP and Fuzzy TOPSIS methods for the performance evaluation. Rouyendegh and Erkan [47] examined a FAHP using triangular fuzzy numbers for selecting the most suitable academic staff. They evaluated and prioritized five candidates under ten different subcriteria.

In the Section 2 and Section 3, FAHP and GRA methodologies are explained, and in Section 4, defuzzification and centroid method are examined. In section 5, the problem is stated, the integrated FAHP-GRA methodology is described, and this methodology is applied to personnel selection. Also the results are computed in this section. The evaluation of the results is given in Section 6.

2. FUZZY ANALYTIC HIERARCHY PROCESS (FAHP) METHODOLOGY

In the FAHP, to evaluate the decision-makers' preferences, pairwise comparisons are structured using triangular fuzzy numbers (a^l, a^m, a^u) as shown in Table 1.

Table 1. Relationship between fuzzy numbers and degrees of linguistic importance

Low/high Levels		Fuzzy Numbers
Label	**Linguistic Terms**	
E	Just equal	(1,1,1)
SL	Slightly Low	(1,1,3)
M	Middle	(1,3,5)
SH	Slightly High	(3,5,7)
H	High	(5,7,9)
VH	Very High	(7,9,9)

The $m \times n$ fuzzy matrix can be given as in (1). The element a_{mn} represents the comparison of the component m (row element) with component n (column element). If $\tilde{A}$ is a pairwise comparison matrix (1), it is assumed that the reciprocal, and the reciprocal value, i.e. $1/a_{mn}$ is assigned to the element a_{mn} [48-50]:

$$\widetilde{A} = \begin{bmatrix} (1,1,1) & \cdots & (a_{1n}^{l}, a_{1n}^{m}, a_{1n}^{u}) \\ \vdots & \ddots & \vdots \\ (1/a_{1n}^{u}, 1/a_{1n}^{m}, 1/a_{1n}^{l}) & \cdots & (1,1,1) \end{bmatrix} \quad (1)$$

Zadeh [51] introduced the fuzzy set theory to deal with the uncertainty due to imprecision and vagueness. A major contribution of fuzzy set theory is its capability of representing vague data. A triangular fuzzy number that defined as (l, m, u), where $(l \leq m \leq u)$, denote the smallest possible value, the most promising value and the largest possible value.

The steps of fuzzy AHP can be listed as follows [34, 50, 52]:
Step 1: Determine alternatives, criteria and subcriteria to be used in the model.

Step 2: Create a hierarchy including goal, criteria, subcriteria, and alternatives.

Step 3: Evaluate the relative importance of the criteria using pairwise comparisons. Assign linguistic terms to the pairwise comparisons by asking which criterion is more important than the other with fuzzy numbers.

$$\widetilde{A} = \begin{bmatrix} 1 & \cdots & \tilde{a}_{1n} \\ \vdots & \ddots & \vdots \\ \tilde{a}_{n1} & \cdots & 1 \end{bmatrix} = \begin{bmatrix} 1 & \cdots & \tilde{a}_{1n} \\ \vdots & \ddots & \vdots \\ 1/\tilde{a}_{1n} & \cdots & 1 \end{bmatrix} \quad (2)$$

Step 4: Define the fuzzy geometric mean and fuzzy weight of each criterion.

$$\tilde{r}_i = \left(\tilde{a}_{i1} \otimes \tilde{a}_{i2} \otimes \ldots \otimes \tilde{a}_{in}\right)^{1/n} \quad (3)$$

$$\widetilde{w}_i = \tilde{r}_i \otimes (\tilde{r}_1 \oplus \ldots \oplus \tilde{r}_n)^{-1} \quad (4)$$

where $\tilde{a}_{in}$ is the fuzzy comparison value of criterion i to criterion n, thus, $\tilde{r}_i$ is the geometric mean of fuzzy comparison value of criterion i to each criterion, $\widetilde{w}_i$ is the fuzzy weight of the i^{th} criterion. $\widetilde{w}_i = (l_{w_i}, m_{w_i}, u_{w_i})$. l_{w_i} means lower, m_{w_i} means middle and u_{w_i} means upper values of the fuzzy weight of the i^{th} criterion. Moreover, two triangular fuzzy numbers can be denoted by (l_1, m_1, u_1) and (l_2, m_2, u_2), respectively. "$\oplus$" and "$\otimes$" are the operational laws of two triangular fuzzy numbers [34].

Addition of two fuzzy numbers is defined by

$$(l_1, m_1, u_1) \oplus (l_2, m_2, u_2) = (l_1 + l_2, m_1 + m_2, u_1 + u_2).$$

Multiplication of two fuzzy numbers is defined by

$$(l_1, m_1, u_1) \otimes (l_2, m_2, u_2) = (l_1 l_2, m_1 m_2, u_1 u_2).$$

Step 5: Defuzzify and normalize the fuzzy weights.

3. GREY RELATIONAL ANALYSIS (GRA) METHODOLOGY

Grey system theory was proposed by [18] and was born by the concept of grey set. The major advantage of grey theory is that it is suitable to handle both incomplete information and unclear problems [24]. The Grey relational analysis uses information from the Grey system to dynamically compare each factor quantitatively [17].

The steps of GRA are as shown below [17, 24]:

Step 1: Generation of Grey relation (Data processing):

The expected goal for each factor is determined by [53, 54] based on the principles of data processing. They are described in the following [17, 24]:

1. If the expectancy is larger-the-better, then it can be expressed by

$$x_i^*(j) = \frac{x_i(j) - min x_i(j)}{max x_i(j) - min x_i(j)} \tag{5}$$

2. If the expectancy is smaller-the-better, then it can be expressed by

$$x_i^*(j) = \frac{max x_i(j) - x_i(j)}{max x_i(j) - min x_i(j)} \tag{6}$$

where i (alternatives), j (criteria) [24].

Step 2: Determination of the Grey relational coefficient:

The Grey relational coefficient can be defined as $\gamma_i(j)$ and it can be expressed as following [17, 24]:

$$\gamma_i(j) = \frac{\Delta min + \Delta max}{\Delta_i(j) + \Delta max} \tag{7}$$

where $\Delta min = \min_i \min_j \Delta_i(j)$, $\Delta max = \max_i \max_j \Delta_i(j)$, x_0^* is a referenced series (the grade of local Grey relation), x_i^* is a specific comparative series (the grade of global Grey relation) and $\Delta_i(j) = |x_0^*(j) - x_i^*(j)|$, representing the j 's absolute value of the difference of $x_0^*(j)$ and $x_i^*(j)$.

Step 3: Determination of the Grey relational grade:

After obtaining the Grey relational coefficient, take the average of the Grey relational coefficient to find the Grey relational grade [17, 24]:

$$\Gamma_i = \frac{1}{n}\sum_{j=1}^{n} \gamma_i(j) \tag{8}$$

Step 4: Select the alternative with larger grey relational grade.

4. DEFUZZIFICATION AND CENTROID METHOD

There may be situations where the output of a fuzzy process needs to be a single scalar quantity as opposed to a fuzzy set. Defuzzification is the conversion of a fuzzy quantity to a precise quantity [55].

Centroid method: This procedure (also called center of area, center of gravity) is the most prevalent and physically appealing of all the defuzzification methods [56, 57]; it is given by the algebraic expression

$$z^* = \frac{\int_z \mu_{c'}(z) z \, dz}{\int_z \mu_{c'}(z) \, dz} \tag{9}$$

here $\int$ denotes an algebraic integration and z^* is the defuzzified value [55].

Centroid defuzzification method finds a point representing the centre of gravity of the fuzzy set, c'.

Moreover, $c' = (l, m, u)$ is a fuzzy set on $\mathbb{R} = (-\infty, \infty)$ and called a triangular fuzzy number and its membership function $\mu_{c'}(z)$: $\mathbb{R} \rightarrow [0,1]$ is equal to

$$\mu_{c'}(z) = \begin{cases} (z-l)(m-l), & if \;\; l \le z \le m, \\ (u-z)(u-m), & if \;\; m \le z \le u, \\ 0, & otherwise, \end{cases}$$

where l and u stand for the lower and upper bounds of the fuzzy number c', respectively and m for the modal value $(l < m < u)$ [34]. Namely, $\mu_{c'}(z)$ represents a mapping which maps each element z to a real number in the closed interval [0,1].

5. PROBLEM DEFINITION AND APPLICATION: A REAL CASE STUDY

In this section, we studied personnel selection criteria and we aimed to prioritize the personnel using integrated Multi Criteria Decision Making (MCDM) techniques, Fuzzy Analytic Hierarchy Process (FAHP) and Grey Relational Analysis (GRA). The proposed model uses the FAHP to calculate the importance weights of personnel according to personnel selection criteria (Table 1). Then, obtained fuzzy importance weights are defuzzified by centroid method. After that, defuzzified importance weights of personnel are integrated with the GRA to prioritize the alternatives. The main steps of the integrated FAHP-GRA are as follows (Figure 1):

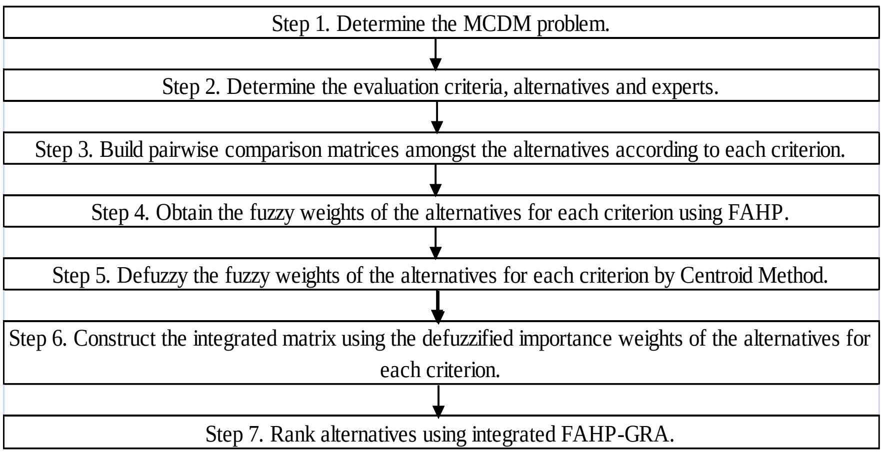

Figure 1. Procedure of the proposed methodology

Step 1: Personnel selection problem for a firm in Istanbul, Turkey was chosen for this study and an integrated FAHP-GRA approach was used.

Step 2: The firm aims to promote one of the engineers with a chief-engineer position. We asked three experts from university and the firm for personnel selection. 5 main criteria and 22 subcriteria were determined according to the views of the academicians and the managers of the firm [2]. 17 alternatives were determined according to the views of the managers. Then these alternatives were weighted. For this personnel selection problem, decision criteria (main and subcriteria) can be seen in Table 2.

Table 2. Criteria of personnel selection [2].

Main Criteria		Subcriteria	
MC1	ACTIVITY	SC11	Productive Activity
		SC12	Auxiliary Activity
		SC13	Inefficient Activity
MC2	FEE	SC21	Fee Paid
		SC22	Payable Fee
		SC23	Requested Fee
MC3	EDUCATION	SC31	Education Status
		SC32	Foreign Languages
		SC33	Certificates
		SC34	Job Experience
		SC35	Technology Usage
		SC36	Lifelong Learning
MC4	INTERNAL FACTORS	SC41	Self-Confidence
		SC42	Take Initiative
		SC43	Analytic Thinking
		SC44	Leadership
		SC45	Productivity
		SC46	Decision Making / Problem Solving
MC5	BUSINESS FACTORS	SC51	Compatible with the Team / Communication
		SC52	Teamwork Skills
		SC53	Finishing Work on Time
		SC54	Business Discipline

Step 3: All experts were asked to determine the importance weight of alternatives with respect to subcriteria based on Table 2. The pairwise comparison matrix of subcriteria (SC11) for one expert can be seen in Table 3. Then, pairwise comparison matrix for each subcriteria are made.

Step 4: Then the geometric mean of fuzzy comparison value of subcriteria (SC11) are calculated in Table 4. The weighted normalized fuzzy decision matrix is also calculated according to the FAHP methodology. The respected results are reported in Table 5. Then, the fuzzy weights of the alternatives for each subcriteria are obtained by using FAHP.

Step 5: Then, fuzzy importance weights obtained from all experts are defuzzified by centroid method in Table 6. Then, the fuzzy weights of the alternatives for each subcriteria are defuzzified by using centroid method.

Step 6: The defuzzified importance weights of personnel according to personnel selection criteria are integrated with a GRA model in Table 7.

Step 7: The expected goal for each personnel according to personnel selection criteria are determined using (5), (6) as shown in Table 8. Also, an ideal standard series (x_0) is established in the last line in Table 8.

The Grey relational coefficient for each personnel are calculated by (7) and shown in Table 9.

The Grey relational grade for each personnel are calculated by (8) and shown in Table 10.

Table 3. The pairwise comparison of alternatives with respect to subcriteria SC11

	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14	A15	A16	A17
A1	(1,1,1)	(3,5,7)	(1,1,3)	(1,1,3)	(1,3,5)	(1,1,3)	(1,3,5)	(3,5,7)	(0.14,0.2,0.33)	(0.2,0.33,1)	(0.33,1,1)	(1,1,3)	(1,1,3)	(1,1,1)	(0.2,0.33,1)	(0.33,1,1)	(1,1,3)
A2	(0.14,0.2,0.33)	(1,1,1)	(1,1,3)	(1,3,5)	(1,1,3)	(1,3,5)	(1,1,3)	(1,3,5)	(0.2,0.33,1)	(1,1,3)	(1,3,5)	(1,1,3)	(1,1,3)	(1,3,5)	(1,1,3)	(1,1,3)	(1,3,5)
A3	(0.33,1,1)	(0.33,1,1)	(1,1,1)	(1,1,3)	(1,3,5)	(1,1,3)	(1,1,3)	(1,1,3)	(0.14,0.2,0.33)	(0.2,0.33,1)	(1,1,3)	(1,1,3)	(1,3,5)	(1,3,5)	(1,1,3)	(1,3,5)	(1,3,5)
A4	(0.33,1,1)	(0.2,0.33,1)	(0.33,1,1)	(1,1,1)	(1,1,3)	(1,3,5)	(1,1,3)	(1,1,3)	(0.2,0.33,1)	(1,1,3)	(1,1,3)	(1,1,3)	(1,1,3)	(1,1,3)	(1,1,3)	(1,1,3)	(1,1,3)
A5	(0.2,0.33,1)	(0.33,1,1)	(0.2,0.33,1)	(0.33,1,1)	(1,1,1)	(1,1,3)	(1,3,5)	(1,1,3)	(0.14,0.2,0.33)	(0.2,0.33,1)	(1,1,3)	(1,3,5)	(1,1,3)	(1,1,3)	(1,1,3)	(1,1,3)	(1,1,3)
A6	(0.33,1,1)	(0.2,0.33,1)	(0.33,1,1)	(0.2,0.33,1)	(0.33,1,1)	(1,1,1)	(1,3,5)	(1,3,5)	(0.2,0.33,1)	(0.2,0.33,1)	(1,3,5)	(1,1,3)	(1,1,3)	(1,1,3)	(1,3,5)	(1,3,5)	(1,3,5)
A7	(0.2,0.33,1)	(0.33,1,1)	(0.33,1,1)	(0.33,1,1)	(0.2,0.33,1)	(0.2,0.33,1)	(1,1,1)	(1,1,3)	(0.14,0.2,0.33)	(0.2,0.33,1)	(1,1,1)	(1,1,3)	(1,1,3)	(1,1,3)	(1,1,3)	(1,1,3)	(1,1,3)
A8	(0.14,0.2,0.33)	(0.2,0.33,1)	(0.33,1,1)	(0.33,1,1)	(0.33,1,1)	(0.2,0.33,1)	(0.33,1,1)	(1,1,1)	(0.2,0.33,1)	(0.2,0.33,1)	(1,1,3)	(1,1,3)	(1,1,3)	(1,1,3)	(1,1,3)	(1,3,5)	(1,3,5)
A9	(3,5,7)	(1,3,5)	(3,5,7)	(1,3,5)	(3,5,7)	(1,3,5)	(3,5,7)	(1,3,5)	(1,1,1)	(1,3,5)	(3,5,7)	(1,1,3)	(1,3,5)	(1,3,5)	(1,1,3)	(1,3,5)	(3,5,7)
A10	(1,3,5)	(0.33,1,1)	(1,3,5)	(0.33,1,1)	(1,3,5)	(1,3,5)	(1,3,5)	(1,3,5)	(0.2,0.33,1)	(1,1,1)	(1,1,3)	(1,3,5)	(1,1,3)	(1,1,3)	(1,3,5)	(1,3,5)	(1,3,5)
A11	(1,1,3)	(0.2,0.33,1)	(0.33,1,1)	(0.33,1,1)	(0.33,1,1)	(0.2,0.33,1)	(1,1,1)	(0.33,1,1)	(0.14,0.2,0.33)	(0.33,1,1)	(1,1,1)	(1,1,3)	(1,1,3)	(1,1,3)	(1,1,3)	(1,1,3)	(1,1,3)
A12	(0.33,1,1)	(0.33,1,1)	(0.33,1,1)	(0.33,1,1)	(0.2,0.33,1)	(0.33,1,1)	(0.33,1,1)	(0.33,1,1)	(0.33,1,1)	(0.2,0.33,1)	(0.33,1,1)	(1,1,1)	(1,1,3)	(1,1,3)	(1,1,3)	(1,3,5)	(1,1,3)
A13	(0.33,1,1)	(0.33,1,1)	(0.2,0.33,1)	(0.33,1,1)	(0.33,1,1)	(0.33,1,1)	(0.33,1,1)	(0.33,1,1)	(0.2,0.33,1)	(0.33,1,1)	(0.33,1,1)	(0.33,1,1)	(1,1,1)	(1,1,3)	(1,1,3)	(1,1,3)	(1,1,3)
A14	(1,1,1)	(0.2,0.33,1)	(0.2,0.33,1)	(0.33,1,1)	(0.33,1,1)	(0.33,1,1)	(0.33,1,1)	(0.33,1,1)	(0.2,0.33,1)	(0.33,1,1)	(0.33,1,1)	(0.33,1,1)	(0.33,1,1)	(1,1,1)	(1,1,3)	(1,1,3)	(1,1,3)
A15	(1,3,5)	(0.33,1,1)	(0.33,1,1)	(0.33,1,1)	(0.33,1,1)	(0.2,0.33,1)	(0.33,1,1)	(0.33,1,1)	(0.33,1,1)	(0.2,0.33,1)	(0.33,1,1)	(0.33,1,1)	(0.33,1,1)	(0.33,1,1)	(1,1,1)	(1,1,3)	(1,1,3)
A16	(1,1,3)	(0.33,1,1)	(0.2,0.33,1)	(0.33,1,1)	(0.33,1,1)	(0.2,0.33,1)	(0.33,1,1)	(0.2,0.33,1)	(0.2,0.33,1)	(0.2,0.33,1)	(0.33,1,1)	(0.20,0.33,1)	(0.33,1,1)	(0.33,1,1)	(0.33,1,1)	(1,1,1)	(1,1,3)
A17	(0.33,1,1)	(0.2,0.33,1)	(0.2,0.33,1)	(0.33,1,1)	(0.33,1,1)	(0.2,0.33,1)	(0.33,1,1)	(0.2,0.33,1)	(0.14,0.2,0.33)	(0.2,0.33,1)	(0.33,1,1)	(0.33,1,1)	(0.33,1,1)	(0.33,1,1)	(0.33,1,1)	(0.33,1,1)	(1,1,1)

Table 4. The geometric mean of fuzzy comparison value of subcriteria (SC11)

	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14	A15	A16	A17
l	0.738	0.811	0.713	0.727	0.590	0.564	0.503	0.472	1.474	0.799	0.534	0.463	0.434	0.421	0.406	0.338	0.291
m	1.099	1.257	1.178	0.937	0.853	1.138	0.702	0.799	2.960	1.789	0.799	0.937	0.879	0.824	0.937	0.679	0.658
u	2.099	2.774	2.366	2.238	1.900	2.142	1.474	1.565	4.823	3.129	1.474	1.424	1.295	1.214	1.251	1.138	0.937

Table 5. The weighted normalized fuzzy decision matrix of subcriteria (SC11)

	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14	A15	A16	A17
l	0.022	0.024	0.021	0.022	0.018	0.017	0.015	0.014	0.044	0.024	0.016	0.014	0.013	0.013	0.012	0.010	0.009
m	0.060	0.068	0.064	0.051	0.046	0.062	0.038	0.043	0.161	0.097	0.043	0.051	0.048	0.045	0.051	0.037	0.036
u	0.204	0.270	0.230	0.218	0.185	0.208	0.143	0.152	0.469	0.304	0.143	0.139	0.126	0.118	0.122	0.111	0.091

Table 6. The defuzzified importance weights of personnel by centroid method for subcriteria SC11

A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14	A15	A16	A17
0.101	0.120	0.113	0.099	0.086	0.086	0.064	0.066	0.222	0.136	0.070	0.067	0.058	0.057	0.054	0.051	0.039

Table 7. Integrated model's importance weight matrix

	SC11	SC12	SC13	SC21	SC22	SC23	SC31	SC32	SC33	SC34	SC35	SC36	SC41	SC42	SC43	SC44	SC45	SC46	SC51	SC52	SC53	SC54
A1	0.101	0.094	0.116	0.131	0.120	0.131	0.053	0.094	0.055	0.138	0.054	0.055	0.136	0.096	0.128	0.093	0.132	0.096	0.128	0.054	0.095	0.111
A2	0.120	0.120	0.152	0.154	0.155	0.132	0.110	0.120	0.105	0.135	0.106	0.108	0.141	0.123	0.135	0.120	0.137	0.120	0.138	0.107	0.118	0.135
A3	0.113	0.153	0.120	0.123	0.115	0.138	0.067	0.143	0.075	0.135	0.063	0.060	0.135	0.105	0.138	0.103	0.135	0.105	0.134	0.065	0.100	0.120
A4	0.099	0.101	0.095	0.112	0.136	0.131	0.106	0.098	0.102	0.132	0.097	0.104	0.127	0.103	0.133	0.095	0.132	0.097	0.123	0.100	0.095	0.126
A5	0.086	0.122	0.091	0.095	0.109	0.105	0.113	0.126	0.124	0.108	0.122	0.122	0.104	0.089	0.109	0.089	0.105	0.082	0.104	0.125	0.087	0.110
A6	0.086	0.093	0.102	0.094	0.095	0.095	0.121	0.091	0.122	0.092	0.113	0.116	0.088	0.090	0.088	0.101	0.091	0.099	0.093	0.119	0.094	0.103
A7	0.064	0.081	0.088	0.087	0.087	0.090	0.136	0.083	0.124	0.085	0.134	0.133	0.088	0.065	0.095	0.070	0.094	0.073	0.089	0.138	0.069	0.100
A8	0.066	0.074	0.084	0.070	0.095	0.080	0.072	0.079	0.073	0.081	0.073	0.069	0.074	0.067	0.078	0.074	0.080	0.075	0.083	0.075	0.073	0.083
A9	0.222	0.212	0.192	0.159	0.161	0.187	0.193	0.206	0.190	0.185	0.189	0.189	0.196	0.226	0.198	0.226	0.201	0.227	0.189	0.200	0.227	0.192
A10	0.136	0.077	0.069	0.064	0.071	0.076	0.074	0.081	0.081	0.078	0.076	0.071	0.079	0.142	0.076	0.148	0.078	0.142	0.076	0.073	0.136	0.078
A11	0.070	0.076	0.068	0.068	0.074	0.071	0.109	0.079	0.109	0.073	0.105	0.098	0.078	0.068	0.073	0.065	0.079	0.069	0.071	0.110	0.072	0.082
A12	0.067	0.063	0.057	0.056	0.061	0.067	0.070	0.067	0.069	0.071	0.073	0.067	0.074	0.071	0.070	0.066	0.065	0.066	0.080	0.068	0.070	0.071
A13	0.058	0.058	0.062	0.050	0.061	0.070	0.082	0.062	0.083	0.072	0.083	0.082	0.065	0.065	0.064	0.061	0.064	0.056	0.075	0.082	0.062	0.072
A14	0.057	0.056	0.059	0.042	0.052	0.058	0.089	0.067	0.086	0.057	0.094	0.094	0.061	0.059	0.056	0.055	0.053	0.060	0.062	0.075	0.056	0.065
A15	0.054	0.055	0.047	0.043	0.047	0.051	0.066	0.057	0.063	0.045	0.067	0.069	0.050	0.058	0.050	0.060	0.046	0.061	0.053	0.067	0.063	0.052
A16	0.051	0.049	0.047	0.041	0.041	0.047	0.084	0.051	0.079	0.051	0.085	0.090	0.049	0.057	0.048	0.047	0.047	0.055	0.051	0.082	0.053	0.051
A17	0.039	0.041	0.041	0.036	0.039	0.041	0.063	0.043	0.066	0.045	0.068	0.074	0.042	0.045	0.041	0.043	0.042	0.044	0.046	0.068	0.042	0.049

Table 8. The expected goal for each personnel according to personnel selection criteria.

	SC11	SC12	SC13	SC21	SC22	SC23	SC31	SC32	SC33	SC34	SC35	SC36	SC41	SC42	SC43	SC44	SC45	SC46	SC51	SC52	SC53	SC54
A1	0.341	0.313	0.496	0.773	0.669	0.615	0.000	0.311	0.000	0.660	0.000	0.000	0.606	0.281	0.552	0.272	0.567	0.285	0.573	0.000	0.290	0.429
A2	0.440	0.461	0.734	0.962	0.956	0.624	0.407	0.470	0.375	0.641	0.382	0.398	0.641	0.432	0.597	0.423	0.599	0.418	0.641	0.363	0.412	0.598
A3	0.402	0.655	0.519	0.709	0.624	0.666	0.101	0.614	0.147	0.643	0.067	0.039	0.601	0.332	0.618	0.327	0.585	0.336	0.612	0.080	0.317	0.492
A4	0.325	0.352	0.357	0.616	0.795	0.617	0.380	0.335	0.353	0.617	0.321	0.362	0.550	0.319	0.589	0.287	0.565	0.289	0.536	0.314	0.286	0.533
A5	0.254	0.476	0.332	0.483	0.573	0.436	0.428	0.512	0.513	0.449	0.506	0.499	0.402	0.247	0.431	0.251	0.397	0.209	0.406	0.485	0.247	0.427
A6	0.258	0.307	0.405	0.469	0.457	0.372	0.484	0.294	0.498	0.331	0.440	0.453	0.301	0.250	0.302	0.319	0.305	0.304	0.328	0.449	0.285	0.372
A7	0.134	0.237	0.312	0.417	0.391	0.332	0.592	0.247	0.514	0.284	0.590	0.579	0.298	0.110	0.341	0.149	0.329	0.160	0.296	0.575	0.150	0.352
A8	0.146	0.192	0.281	0.274	0.458	0.268	0.139	0.217	0.138	0.257	0.144	0.102	0.206	0.126	0.232	0.169	0.236	0.172	0.259	0.143	0.168	0.236
A9	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
A10	0.530	0.211	0.186	0.231	0.262	0.236	0.150	0.229	0.192	0.232	0.161	0.117	0.239	0.539	0.223	0.571	0.228	0.540	0.210	0.133	0.508	0.198
A11	0.167	0.203	0.176	0.260	0.284	0.206	0.396	0.217	0.400	0.195	0.376	0.323	0.236	0.128	0.204	0.123	0.234	0.137	0.172	0.383	0.162	0.229
A12	0.152	0.132	0.104	0.162	0.181	0.179	0.120	0.145	0.104	0.182	0.139	0.087	0.210	0.145	0.183	0.129	0.145	0.125	0.234	0.100	0.153	0.150
A13	0.103	0.101	0.135	0.110	0.180	0.198	0.208	0.116	0.206	0.188	0.219	0.198	0.148	0.113	0.147	0.099	0.135	0.066	0.199	0.194	0.112	0.159
A14	0.099	0.091	0.116	0.046	0.105	0.118	0.255	0.143	0.229	0.085	0.298	0.290	0.121	0.077	0.093	0.068	0.067	0.087	0.108	0.149	0.080	0.108
A15	0.081	0.080	0.039	0.056	0.063	0.067	0.091	0.084	0.058	0.001	0.093	0.102	0.049	0.072	0.059	0.095	0.027	0.096	0.046	0.092	0.114	0.022
A16	0.066	0.045	0.039	0.043	0.014	0.042	0.219	0.044	0.177	0.042	0.232	0.264	0.047	0.067	0.043	0.021	0.028	0.061	0.034	0.194	0.060	0.013
A17	0.000	0.000	0.000	0.000	0.000	0.000	0.071	0.000	0.082	0.000	0.103	0.141	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.100	0.000	0.000
Std. s.	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

Table 9. The Grey relational coefficient for each personnel according to personnel selection criteria.

	SC11	SC12	SC13	SC21	SC22	SC23	SC31	SC32	SC33	SC34	SC35	SC36	SC41	SC42	SC43	SC44	SC45	SC46	SC51	SC52	SC53	SC54
A1	0.603	0.593	0.665	0.815	0.751	0.722	0.500	0.592	0.500	0.746	0.500	0.500	0.717	0.582	0.691	0.579	0.698	0.583	0.701	0.500	0.585	0.636
A2	0.641	0.650	0.790	0.964	0.958	0.727	0.628	0.653	0.615	0.736	0.618	0.624	0.736	0.638	0.713	0.634	0.714	0.632	0.736	0.611	0.630	0.713
A3	0.626	0.743	0.675	0.775	0.727	0.750	0.527	0.722	0.540	0.737	0.517	0.510	0.715	0.600	0.723	0.598	0.707	0.601	0.720	0.521	0.594	0.663
A4	0.597	0.607	0.609	0.722	0.830	0.723	0.617	0.601	0.607	0.723	0.596	0.610	0.690	0.595	0.709	0.584	0.697	0.585	0.683	0.593	0.583	0.682
A5	0.573	0.656	0.600	0.659	0.701	0.639	0.636	0.672	0.672	0.645	0.669	0.666	0.626	0.570	0.637	0.572	0.624	0.558	0.628	0.660	0.570	0.636
A6	0.574	0.591	0.627	0.653	0.648	0.614	0.659	0.586	0.666	0.599	0.641	0.647	0.589	0.571	0.589	0.595	0.590	0.590	0.598	0.645	0.583	0.614
A7	0.536	0.567	0.593	0.632	0.621	0.600	0.710	0.570	0.673	0.583	0.709	0.704	0.588	0.529	0.603	0.540	0.598	0.543	0.587	0.702	0.541	0.607
A8	0.539	0.553	0.582	0.579	0.648	0.577	0.537	0.561	0.537	0.574	0.539	0.527	0.557	0.533	0.566	0.546	0.567	0.547	0.574	0.538	0.546	0.567
A9	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
A10	0.680	0.559	0.551	0.565	0.575	0.567	0.540	0.565	0.553	0.566	0.544	0.531	0.568	0.684	0.563	0.700	0.564	0.685	0.559	0.535	0.670	0.555
A11	0.546	0.557	0.548	0.575	0.583	0.557	0.623	0.561	0.625	0.554	0.616	0.596	0.567	0.534	0.557	0.533	0.566	0.537	0.547	0.618	0.544	0.565
A12	0.541	0.535	0.528	0.544	0.550	0.549	0.532	0.539	0.527	0.550	0.537	0.523	0.559	0.539	0.550	0.535	0.539	0.533	0.566	0.526	0.541	0.541
A13	0.527	0.527	0.536	0.529	0.549	0.555	0.558	0.531	0.557	0.552	0.561	0.555	0.540	0.530	0.540	0.526	0.536	0.517	0.555	0.554	0.530	0.543
A14	0.526	0.524	0.531	0.512	0.528	0.531	0.573	0.538	0.565	0.522	0.587	0.585	0.532	0.520	0.524	0.517	0.517	0.523	0.529	0.540	0.521	0.528
A15	0.521	0.521	0.510	0.514	0.516	0.517	0.524	0.522	0.515	0.500	0.524	0.527	0.513	0.519	0.515	0.525	0.507	0.525	0.512	0.524	0.530	0.505
A16	0.517	0.511	0.510	0.511	0.504	0.511	0.562	0.511	0.549	0.511	0.566	0.576	0.512	0.517	0.511	0.505	0.507	0.516	0.509	0.554	0.516	0.503
A17	0.500	0.500	0.500	0.500	0.500	0.500	0.518	0.500	0.521	0.500	0.527	0.538	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.526	0.500	0.500

Table 10. The Grey relational grade for each personnel

A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14	A15	A16	A17
0.625	0.698	0.650	0.647	0.630	0.612	0.606	0.559	1.000	0.586	0.569	0.540	0.541	0.535	0.518	0.522	0.506

According to the results shown in Table 10, the ranking of personnel is obtained as A9>A2>A3>A4>A5>A1>A6>A7>A10>A11>A8>A13>A12>A14>A16>A15>A17. Given these results, it is fair to say that selecting Personnel A9 is the most reasonable outcome, followed by the others.

6. CONCLUSION

Personnel selection is crucial for business life. The aim of this paper is to determine the best personnel by using the integrated Fuzzy Analytic Hierarchy Process (FAHP) and Grey Relational Analysis (GRA) methodology. We integrated two MCDM methods to select the best personnel, namely Fuzzy Analytic Hierarchy Process (FAHP) and Grey Relational Analysis (GRA). Firstly the importance weights of the personnel according to personnel selection criteria are determined using FAHP and fuzzy importance weights are defuzzified by centroid method. Then the personnel are prioritized according to these weights using GRA methodology. The Grey relational analysis requires less data and can analyze many factors by overcoming drawbacks of statistics method [17]. As a result of the evaluation process, the ranking of the personnel is found as A9>A2>A3>A4>A5>A1 followed by the others.

The main contribution of this study is to reduce data using the integrated methodology. So, the number of transactions decreases and working on less data increases the efficiency of the results. As regards future researches, the problem could be solved by other integrated MCDM techniques.

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