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An integrated dynamic intuitionistic fuzzy MADM approach for personnel promotion problem

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Abstract

Purpose – One of the key success factors for an organization is the promotion of qualified personnel for vacant positions. Especially, the promotion of middle and senior managers play an important role in terms of organization's success. In personnel promotion problem in which the candidates are nominated within the organization and they have been working for a specific period of time and are known in their organization, the candidates should be evaluated based on their recent as well as past performances to make right selection for the vacant position. For this reason, the purpose of this paper is to propose an integrated dynamic multi-attribute decision-making (MADM) model based on intuitionistic fuzzy set for solving personnel promotion problem.
Design/methodology/approach – The proposed model integrates analytic hierarchy process (AHP) technique and the dynamic evaluation by intuitionistic fuzzy operator for personnel promotion. AHP is employed to determine the weight of attributes based on decision maker's opinions, and the dynamic operator is utilized to aggregate evaluations of candidates for different years. Atanassov's intuitionistic fuzzy set theory is utilized to represent uncertainty and vagueness in MADM process.
Findings – A numerical example is presented to show the applicability of the proposed method for personnel promotion problem and a sensitivity analysis is conducted to demonstrate efficiency of dynamic evaluation. The findings indicate that the varying weights of years employed determined the best candidate for promotion.
Originality/value – The novelty of this study is defining personnel promotion as a MADM problem in the literature for the first time and proposing an integrated dynamic intuitionistic fuzzy MADM approach for the solution, in which the candidates are evaluated at different years.

Keywords Decision making, Operational research, Management, Fuzzy logic
Paper type Research paper

1. Introduction

Human resources is one of the most important assets of a firm, as employees decide how to use basic production sources by playing key roles in using machinery and material resources efficiently and effectively. Regardless of how important machine and material resources are for an organization, making an inadequate decision on selection and/or promotion of employees in human resources may result in channeling available resources in an inefficient way. Therefore, an important component of human resources management, personnel selection process has always been critical for any type of firm activity (Thornton and Gibbons, 2009).

A variety of methods have been developed for selecting the right person for the right job. Some of these methods include tests that attempt to determine the personality

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traits of the applicants for a position, and others attempt to measure the professional knowledge level of the people that are required to fulfill the roles already in that position. Besides, different studies have been conducted where analytical methods are used to understand the process of personnel selection. In these studies, attributes of selection process are determined by using a number of prioritization methods, and candidates are ranked depending on their competencies based on these criteria. Such studies are very beneficial in facilitating the use of combination of quantitative and qualitative factors in process of personnel selection. Using measurable factors in evaluation process does not result in any trouble for decision makers, whereas including non-measurable factors in that process brings about some problems (Balezentis *et al.*, 2012). To overcome such difficulties, fuzzy logic and multi-attribute decision-making (MADM) methods are often used and a more applicable decision-making environment is provided for decision makers.

Personnel promotion problem, on the other hand, is viewed within personnel selection literature. While personnel selection mainly deals with choosing appropriate personnel for an available position from among the applicants outside the firms, personnel promotion problems focus on selecting appropriate personnel for higher positions within the current personnel of that workplace. Compared to personnel selection problems, personnel promotion problems deal with a group of well known and limited number in candidates. Although personnel selection is a frequently researched field in the literature, personnel promotion problem has been rarely studied.

Personnel promotion problem within an organization is defined as the selection by a person or a group, of the most qualified among available candidates for a vacant position, by evaluating key predetermined qualifications looking at candidates' performance during their employment at the company. Since factors such as decision makers, qualifications and selection for the best candidate exists, personnel promotion can be regarded as a MADM problem. To our best knowledge, no published study in the literature has approached the subject of personnel promotion as a MADM problem so far. Additionally, the evaluation of candidates by a group of decision makers risks being uncertain and vague due to a lack of available information about and perceived subjectivity of employees' personal attributes. On the other hand, making the right promotion decision will require the evaluation of candidates based not only on their most current contemporary performance but also the history of past performance over a specific period of employment. For this reason, an integrated dynamic MADM model for personnel promotion problem based on Atanassov's intuitionistic fuzzy set (A-IFS) theory is used in our study to enable the integration of candidates' past performance in the last few years into the promotion evaluation. A-IFS, which is an extension of the fuzzy set theory and more suitable for explaining human reasoning, is utilized to represent the potential uncertainty in decision-making process. Since the required attributes for the vacant position can be tangible and intangible in personnel promotion problem, analytical hierarchy process (AHP) technique that enables pairwise comparison is preferred to determine the weights of attributes. Dynamic intuitionistic fuzzy weighted averaging (DIFWA) operator presented by Xu and Yager (2008) is used to aggregate the evaluations of candidates at different years.

This paper is organized as follows; literature review is introduced in Section 2. AHP method is explained in Section 3. The definitions and properties of A-IFS are briefly presented in Section 4. Section 5 presents the proposed model for personnel promotion problem. A numerical application, a sensitivity analysis and discussion are given in Section 6. Finally, conclusion is given in Section 7.

2. Literature review

Personnel promotion can be viewed as a form of personnel selection problem, although there are no studies that address this problem by MADM techniques in the literature. For this reason, studies related to personnel selection are mentioned in this section. Personnel selection research that use MADM techniques have been widely studied in the literature. Liang and Wang (1994) proposed fuzzy multi-criteria decision-making (MCDM) algorithm to select personnel by objective and subjective evaluations. Karsak (2001) presented a fuzzy MCDM framework-based ideal and anti-ideal solutions concept for the selection of the most suitable candidate. Petrovic-Lazarevic (2001) proposed a two-level personnel selection fuzzy approach with a short list and a hiring decision to minimize subjective judgment of decision makers in the process of distinguishing between appropriate and inappropriate personnel for a job vacancy. Capaldo and Zollo (2001) introduced a fuzzy model to improve the effectiveness of personnel evaluation within a large Italian company. Chen and Cheng (2005) developed a fuzzy MCDM method based on metric distance for information system in project manager selection. Respectively, Gibney and Shang (2007) and Gungor *et al.* (2009) proposed a method based on fuzzy AHP in the personnel selection process. Dursun and Karsak (2010) developed fuzzy MCDM algorithm based on principles of fusion of fuzzy information, two-tuple linguistic representation model, and a technique for order preference by similarity to ideal solution (TOPSIS). Dagdeviren (2010) proposed a hybrid model that combines analytical network process and modified TOPSIS in personnel selection process in the manufacturing systems. Gurbuz (2010) presented a multi-criteria approach using Choquet integral to evaluate the performance of employees. Recently, personnel selection problems have been obtained with different kinds of decision-making techniques such as (Malinowski *et al.*, 2008; Chien and Chen, 2008; Celik *et al.*, 2009; Lin, 2009; Kelemenis and Askounis, 2010).

There are few studies related to DIF-MADM in the literature. Xu and Yager (2008) examined DIF-MADM process when all the attributes are expressed in Atanassov's intuitionistic fuzzy values (A-IFVs) gathered at different periods. They defined intuitionistic fuzzy variable and uncertain intuitionistic fuzzy variable; also DIFWA operator when all the decision information about attributes are shown A-IFSs for different periods and uncertain dynamic intuitionistic fuzzy weighted averaging (UDIFWA) operator when all the decision information about attributes are shown interval-valued IFSs for different periods as new aggregation operators for the first time. They developed two procedures to solve the DIF-MADM problems by using DIFWA operator and UDIFWA operator. They applied their procedures on illustrative examples. Su *et al.* (2011) studied the dynamic intuitionistic fuzzy multi-attribute group decision-making (DIF-MAGDM) problems, in which all the attributes are evaluated by a group of decision makers at different periods by using A-IFVs. They proposed an interactive method to solve the DIF-MAGDM problems. In this method, first, decision makers evaluate the alternatives at different periods by using A-IFVs. Based on the evaluation, the proposed interactive seven step method uses DIFWA operator, the dynamic weighted averaging operator, intuitionistic fuzzy TOPSIS method and the hybrid weighted averaging operator to rank the alternatives and select the best one. The developed method is applied on an illustrative example. Chen and Li (2011) presented a dynamic multi-attribute decision-making (DMADM) model on the basis of triangular A-IFNs to solve DMADM problems and they also asserted that triangular A-IFNs provides more flexible information than triangular fuzzy numbers. When Xu and Cai (2010) mention recent advances in intuitionistic fuzzy information aggregation, they also mention the studies related to DIF-MADM. Peng and Wang (2014) developed the dynamic hesitant fuzzy weighted averaging (DHFWA) operator and the dynamic hesitant fuzzy weighted geometric (DHFWG) operator for decision-making problems where all decision information is provided by decision makers in hesitant fuzzy information from different periods. Bali and Gumus (2014) developed four decision-making procedures using dynamic operators to aggregate the evaluation in different terms and then, grey relational analysis (GRA) and TOPSIS methods are utilized to determine the most appropriate alternative.

3. The AHP method

AHP, developed by Saaty (1980), shows how to rank the relative importance of a set of activities in a MADM problem. The process makes it possible to incorporate judgments on intangible qualitative attributes alongside tangible quantitative attributes (Badri, 2001). AHP method has three important principles: structure of the model, comparative evaluation of the alternatives and the attributes, synthesis of the preferences.

In the first step, a complex decision problem is constructed as a hierarchy. AHP initially breaks down a complex MADM problem into a hierarchy of interrelated decision elements. The second step is the comparison of the alternatives and the attributes. Once the problem has been decomposed and the hierarchy is constructed, prioritization procedure starts in order to determine the relative importance of the attributes within each level. The pairwise judgment starts from the second level and ends in the lowest level (Albayrak and Erensal, 2004). In AHP multiple pairwise comparisons are based on a standardized comparison scale of nine levels (Table I).

The result of the pairwise comparison on m attributes can be summarized in an $(m \times m)$ evaluation matrix A in which every element a_{ij} $(i, j = 1, 2, \ldots, m)$ is the weights of the attributes, as shown in the following equation:

$$A = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1m} \\ a_{21} & a_{22} & \cdots & a_{2m} \\ \vdots & \vdots & \ddots & \vdots \\ a_{m1} & a_{m2} & \cdots & a_{mm} \end{bmatrix}, \quad a_{ii} = 1,\ a_{ji} = 1/a_{ij},\ a_{ij} \neq 0. \tag{1}$$

In the last step, the mathematical process commences to normalize and find the relative weights for each matrix. The relative weights are given by the right eigenvector (w) corresponding to the largest eigenvalue ($\lambda_{\max}$), as:

$$Aw = \lambda_{\max} w. \tag{2}$$

If the pairwise comparisons are completely consistent, the matrix A has rank 1 and $\lambda_{\max} = m$. In this case, weights can be obtained by normalizing any of the rows or columns of A (Wang and Yang, 2007).

Definition	Intensity of importance
Equally important	1
Moderately more important	3
Strongly more important	5
Very strongly more important	7
Extremely more important	9
Intermediate values	2, 4, 6, 8

Table I. Nine-point intensity of importance scale and their description

It should be noted that the quality of the output of the AHP is closely related to the consistency of the pairwise comparison judgments. The consistency is defined by the relation between the entries of A: $a_{ij} \times a_{jk} = a_{ik}$. The consistency index (CI) is:

$$\mathrm{CI} = (\lambda_{\max} - m)/(m-1). \tag{3}$$

The final consistency ratio (CR), using which one can conclude whether the evaluations are sufficiently consistent, is calculated as the ratio of the CI and the random index (RI), as indicated in the following equation:

$$\mathrm{CR} = \mathrm{CI}/\mathrm{RI}. \tag{4}$$

The number 0.1 is the accepted upper limit for CR. If the final CR exceeds this value, the evaluation procedure has to be repeated to improve consistency. The measurement of consistency can be used to evaluate the consistency of decision makers as well as the consistency of all the hierarchy (Wang and Yang, 2007).

4. A-IFS theory

4.1 A-IFS

Zadeh (1965) proposed the theory of fuzzy sets, which has been successfully applied in different fields. In fuzzy sets theory, the membership of any element in fuzzy set has only a single value. This value is defined as membership degree and it takes between 0 and 1 (Wang and Xin, 2005). However, in reality, on-membership degree of an element in a fuzzy set is not certainly equal to 1 minus the membership degree. Because of this, Atanassov (1986) defined some hesitation degree of element in a fuzzy set and described A-IFSs, which are generalization of Zadeh's fuzzy sets. Therefore, the element of A-IFSs has a membership degree, a non-membership degree, and a hesitation degree. A-IFSs have been applied to different kind of decision-making problems such as (Szmidt and Kacprzyk, 2002; Atanassov *et al.*, 2005; Liu and Wang, 2007; Xu, 2007; Agarwal *et al.*, 2013; Zhang *et al.*, 2014):

Definition 1. Let X be a non-empty fixed set and I the closed unit interval [0,1]. An A-IFS A is an object having the form as follows:

$$A = \{ (x, \mu_A(x), v_A(x)) \,|\, x \in X \}, \tag{5}$$

where the mappings μ_A: $X \rightarrow I$ and ν_A: $X \rightarrow I$ denote the degree of membership (namely, $\mu_A(x)$) and the degree of non-membership (namely, $\nu_A(x)$) of each element $x \in X$ to the set A, respectively, and $0 \leqslant \mu_A(x) + \nu_A(x) \leqslant 1$ for each $x \in X$. Obviously, every fuzzy set A on a non-empty set X is an A-IFS having the form:

$$A = \{ (x, \mu_A(x), 1-\mu_A(x)) \,|\, x \in X \}.$$

For a given non-empty set X, denote the family of all A-IFSs in X by the symbol A-IFS(X):

Definition 2. Let X be a non-empty fixed set and $A \in$ A-IFS(X):

$$\pi_A(x) = 1 - \mu_{\mathrm{A}}(x) - v_A(x), \tag{6}$$

known as the Atanassov's intuitionistic fuzzy index or hesitation degree of whether x belongs to A or not. Especially, if $\pi_A(x) = 1 - \mu_{\mathrm{A}}(x) - \nu_A(x) = 0$, for every $x \in X$.

Then, the A-IFS A reduced to a fuzzy set. In addition, $0 \leqslant \pi_A(x) \leqslant 1$:

Definition 3. For every two A-IFSs A, B in X we define the following relations:

1. $A \subset B$ iff $\mu_A(x) \leqslant \mu_B(x)$ *and* $\nu_A(x) \geqslant \nu_B(x)$, for all $x \in X$;
2. $A = B$ iff $\mu_A(x) = \mu_B(x)$ *and* $\nu_A(x) = \nu_B(x)$, for all $x \in X$;
3. $A \cap B = \{\langle x, \min(\mu_A(x), \mu_B(x)), \max(\nu_A(x), \nu_B(x))\rangle | x \in X\}$;
4. $A \cup B = \{\langle x, \max(\mu_A(x), \mu_B(x)), \min(\nu_A(x), \nu_B(x))\rangle | x \in X\}$; and
5. $A \otimes B = \{\langle x, \mu_A(x). \mu_B(x), \nu_A(x) + \nu_B(x) - \nu_A(x). \nu_B(x)\rangle | x \in X\}$.

Definition 4. We call $\alpha = (\mu_A, \nu_A, \pi_A)$ an A-IFV, where $\mu_A \in [0, 1]$, $\nu_A \in [0, 1]$, $0 \leqslant \mu_A + \nu_A \leqslant 1$ and $\pi_A = 1 - \mu_A - \nu_A$.

Definition 5. Let $\alpha_1 = \left(\mu_{\alpha_1}, v_{\alpha_1}, \pi_{\alpha_1}\right)$ and $\alpha_2 = \left(\mu_{\alpha_2}, v_{\alpha_2}, \pi_{\alpha_2}\right)$ be two A-IFVs. The distance between α_1 and α_2 by the following equation:

$$d(\alpha_1, \alpha_2) = \frac{1}{2n}\left(\sum_{i=1}^{n} \left|\mu_{\alpha_1}(x_i) - \mu_{\alpha_2}(x_i)\right| + \left|v_{\alpha_1}(x_i) - v_{\alpha_2}(x_i)\right| + \left|\pi_{\alpha_1}(x_i) - \pi_{\alpha_2}(x_i)\right|\right). \quad (7)$$

This distance definition which is similar to the normalized Hamming distance was given by Szmidt and Kacprzyk (2000).

4.2 DIFWA operator

First introduced by Xu and Yager (2008) DIFWA operator is used to aggregate the evaluation in different years in this study. Assume that $\alpha(t_1), \alpha(t_2), \ldots, \alpha(t_p)$ is A-IFVs to show the values for p different years t_i ($i = 1, 2, \ldots, p$). $\delta(t) = [\delta(t_1), \delta(t_2), \ldots, \delta(t_p)]^T$ is the weight vector of the years, where $\sum_{i=1}^{p} \delta_i = 1$. Xu and Yager (2008) proposed some methods to calculate the weight vector of the years, such as average age method, exponential distribution based method, the basic unit-interval monotonic function-based method and normal distribution based method. DIFWA operator can be calculated practically by using the following equation:

$$DIFWA_{\delta(t)}\left(\alpha(t_1), \alpha(t_2), \ldots, \alpha\left(t_p\right)\right) = \left[1 - \prod_{i=1}^{p}\left(1 - \mu_{\alpha(t_i)}\right)^{\delta(t_i)}, \prod_{i=1}^{p} v_{\alpha(t_i)}^{\delta(t_i)}, \prod_{i=1}^{p}\left(1 - \mu_{\alpha(t_i)}\right)^{\delta(t_i)} - \prod_{i=1}^{p} v_{\alpha(t_i)}^{\delta(t_i)}\right], \quad (8)$$

where $\delta(t_i) \geqslant 0$, $i = 1, \ldots, p$.

5. The integrated dynamic MADM model

In this section, we develop an integrated multi-year MADM model for a personnel promotion problem. In the proposed method, we assumed that decision-making group evaluate candidates for vacant position at different years. The decision-making group use linguistic terms take the form of A-IFSs for the candidates' evaluation. The steps of the proposed model are shown in Figure 1. The following notations are required to describe the developed model:

$X = \{x_1, x_2, \ldots, x_n\}$: a discrete set of n feasible candidates; $A = \{a_1, a_2, \ldots, a_m\}$: a finite set of m determined attributes. $w = (w_1, w_2, \ldots, w_m)^T$ represents the weight vector of the

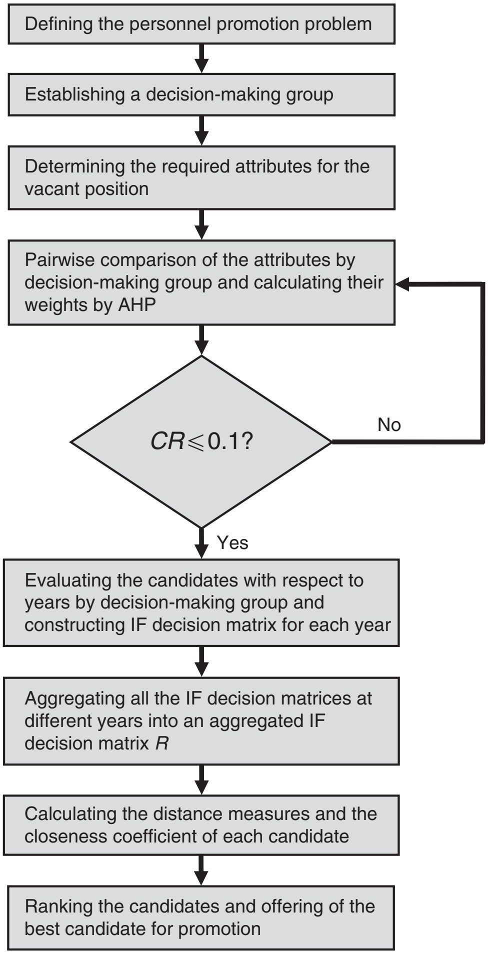

Figure 1.
The steps of the integrated model for personnel promotion problem

attributes, $w_j \geqslant 0$, $j=1, 2, \ldots, m$, $\sum_{j=1}^{m} w_j = 1$ and; there are p years t_k ($i=1, 2, \ldots, p$), whose weight vector is $\delta(t)=(\delta(t_1), \delta(t_2), \ldots, \delta(t_p))^T$, where $\delta(t_k) \geqslant 0$, $\sum_{k=1}^{p} \delta(t_k) = 1$.

Based on information presented above, we present the following steps to offer the best candidate for personnel promotion problem.

Step 1: Establishing a decision-making group.

A decision-making group is set up to determine and evaluate the required attributes and the candidates for the vacant position. To be eligible for promotion, employees must have been working in the company for an extended period of time. Expertise and experience in the field, along with already holding senior positions are also required prerequisites for selection.

Step 2: Determining the required attributes for the vacant position.

Decision-making group determines the required attributes for vacant position to promote the best candidate.

Step 3: Pairwise comparison of the attributes by decision-making group and calculating their weights by AHP.

Decision-making group evaluate the attributes by using importance scale shown in Table I and comparison matrix is constructed as in Equation (1). Then, the weights of attributes are calculated by AHP technique (Equations (2)-(4)). If $CR \geqslant 0.1$, go to next step. If not, Step 3 is repeated.

Step 4: Evaluating the candidates with respect to years by decision-making group and constructing IF decision matrix for each year.

Decision-making group evaluates the candidates taking into account the required attributes for the vacant position and using linguistic terms at each year. Then, intuitionistic fuzzy decision matrix $R(t_i)$ is formed for each year by using A-IFVs corresponding to linguistic terms in evaluation of decision-making group.

Step 5: Aggregating all the intuitionistic fuzzy decision matrices $R(t_i)$ at different years into an aggregated intuitionistic fuzzy decision matrix R.

$R(t_i)$, intuitionistic fuzzy decision matrix for each year is aggregated as R aggregated intuitionistic fuzzy decision matrix by using adapted DIFWA operator in the following equation, practically:

$$\begin{aligned} r_{ij} &= DIFWA_{\delta(t)}\left(r_{ij}(t_1), r_{ij}(t_2), \ldots, r_{ij}(t_p)\right) \\ &= \left(1-\prod_{k=1}^{p}\left(1-\mu_{r_{ij}(t_k)}\right)^{\delta(t_k)}, \prod_{k=1}^{p}\left(v_{r_{ij}(t_k)}\right)^{\delta(t_k)}, \prod_{k=1}^{p}\left(1-\mu_{r_{ij}(t_k)}\right)^{\delta(t_k)} - \prod_{k=1}^{p}\left(v_{r_{ij}(t_k)}\right)^{\delta(t_k)}\right), \end{aligned} \tag{9}$$

where $r_{ij} = (\mu_{ij}, v_{ij}, \pi_{ij})$ is an A-IFV, which represents evaluation of decision-making group. Aggregated intuitionistic fuzzy decision matrix $R = (r_{ij})_{n \times m}$ is obtained by being aggregated the intuitionistic fuzzy decision matrices $R(t_k) = (r_{ij}(t_k))_{n \times m}$ $(k = 1, 2, \ldots, p)$ at different years.

Step 6: Calculating the distance measures and the closeness coefficient of each candidate.

$\alpha^+ = (\alpha_1^+, \alpha_2^+, \ldots, \alpha_m^+)^T$ is defined as the intuitionistic fuzzy ideal solution (IFIS) and $\alpha_i^+ = (1, 0, 0)$ $(i = 1, 2, \ldots, m)$ is the m largest A-IFV. $\alpha^- = (\alpha_1^-, \alpha_2^-, \ldots, \alpha_m^-)^T$ is defined as the intuitionistic fuzzy negative ideal solution (IFNIS) and $\alpha_i^- = (0, 1, 0)$ $(i = 1, 2, \ldots, m)$ is the m smallest A-IFV. The distance between candidate x_i and the IFIS $d(x_i, \alpha^+)$and the distance between candidate x_i and the IFNIS $d(x_i, \alpha^-)$are calculated by using the following equations, respectively:

$$\begin{aligned} d\left(x_i, \alpha^+\right) &= \sum_{j=1}^{m} w_j d\left(r_{ij}, \alpha_j^+\right) = \frac{1}{2m}\sum_{j=1}^{m} w_j\left(\left|\mu_{ij}-1\right| + \left|v_{ij}-0\right| + \left|\pi_{ij}-0\right|\right) \\ &= \sum_{j=1}^{m} w_j\left(1-\mu_{ij}\right), \end{aligned} \tag{10}$$

$$\begin{aligned} d(x_i, \alpha^-) &= \sum_{j=1}^{m} w_j d\left(r_{ij}, \alpha_j^-\right) = \frac{1}{2m}\sum_{j=1}^{m} w_j\left(\left|\mu_{ij}-0\right| + \left|v_{ij}-1\right| + \left|\pi_{ij}-0\right|\right) \\ &= \sum_{j=1}^{m} w_j\left(1-v_{ij}\right), \end{aligned} \tag{11}$$

$c(x_i)$, which is the closeness coefficient of ith candidate is calculated as in the following equation:

$$c(x_i) = \frac{d(x_i, \alpha^-)}{d(x_i, \alpha^+) + d(x_i, \alpha^-)} = \frac{\sum_{j=1}^{m} w_j \left(1 - v_{ij}\right)}{\sum_{j=1}^{m} w_j \left(1 - \mu_{ij}\right) + \sum_{j=}^{m} w_j \left(1 - v_{ij}\right)}$$

$$= \frac{\sum_{j=1}^{m} w_j \left(1 - v_{ij}\right)}{\sum_{j=1}^{m} w_j \left(1 + \pi_{ij}\right)}, \quad i = 1, 2, \ldots, n. \tag{12}$$

Step 7: Ranking the candidates and offering of the best candidate for promotion.

After Step 6, candidates are ranked x_i ($i = 1, 2, \ldots, n$) with respect to their closeness coefficients $c(x_i)$ ($i = 1, 2, \ldots, n$). Finally, the candidate with the highest closeness coefficient is offered as the best personnel who will be promoted.

6. A numerical application

In this section, in order to illustrate the difference of the dynamic evaluation in the personnel promotion problem and the application of the proposed integrated method for selecting the best personnel, a numerical application for a company is presented. The company, founded more than 30 years ago in central Turkey, manufactures electronic devices and systems. The company has more than 2,000 employees. Export and import have an important role for the company as well as in Turkey and in the world. There are four main departments to process orders and requests from customers. One of them is the department of communication and information technologies. The products of this department have an important place among the exported products. This department works on a project basis. In other words, the product is developed upon requests and customer requirements and after customer give approval for it, its production is started. As the products of this department are exported, it accounts for an important part of the revenues of the company. The head of the department of communication and information technologies will be selected and five candidates have been nominated for this position. Working years of the candidates in the company are different. Hence, the candidates in the last three years (2012-2014) will be considered for evaluation.

Step 1: Establishing a decision-making group.

The board of directors has appointed of a group of five people who are top managers for the selection of the head of communications and information technologies department. Group members have been working in the company for at least five years and they have known the candidates for the last three years.

Step 2: Determining the required attributes for the vacant position.

Decision-making group has determined the required attributes for the position as follows:

a_1: business units, a_2: past experience, a_3: team player, a_4: fluency in a foreign language, a_5: strategic thinking, a_6: computer skills, a_7: leadership.

Step 3: Pairwise comparison of the attributes by decision-making group and calculating their weights by AHP.

Decision-making group has evaluated the attributes as in Table II. The weights of attributes are calculated by using Equations (2)-(4). Since CR is less than 0.1, we can go to the next step. In this application, it is assumed that the importance degrees of attributes do not change in years.

Step 4: Evaluating the candidates with respect to years by decision-making group and constructing IF decision matrix for each year.

Decision-making group has evaluated candidates for seven attributes using linguistic terms in Table III for the years 2012-2014. These evaluations are shown in Tables IV-VI.

	a_1	a_2	a_3	a_4	a_5	a_6	a_7	Weights
a_1	1	2	3	7	3	7	1	0.278
a_2		1	3	3	1/2	4	1/3	0.125
a_3			1	3	1/4	4	1/4	0.081
a_4				1	1/5	2	1/5	0.042
a_5					1	5	1/2	0.177
a_6						1	1/6	0.031
a_7							1	0.266
CR = 0.04								

Table II. Evaluation matrix for attributes

Linguistic terms	A-IFVs
Extremely good (E)	(1.00,0.00,0.00)
Very very good (VVG)	(0.90,0.10,0.00)
Very good (VG)	(0.80,0.10,0.10)
Good (G)	(0.70,0.20,0.10)
Medium good (MG)	(0.60,0.30,0.10)
Medium (M)	(0.50,0.40,0.10)
Medium bad (MB)	(0.40,0.50,0.10)
Bad (B)	(0.25,0.60,0.15)
Very bad (VB)	(0.10,0.75,0.15)
Very very bad (VVB)	(0.10,0.90,0.00)

Table III. Linguistic terms and A-IFVs

	a_1	a_2	a_3	a_4	a_5	a_6	a_7
x_1	MG	F	VG	MB	MG	G	MG
x_2	VG	G	VG	G	MG	MG	MG
x_3	MG	MG	VG	F	G	F	MG
x_4	VG	F	VG	MB	G	MG	VG
x_5	MG	F	MG	G	VG	G	MG

Table IV. Evaluation for $R(t_1) = 2012$

	a_1	a_2	a_3	a_4	a_5	a_6	a_7
x_1	MG	MG	VG	MG	MG	VG	G
x_2	G	G	G	VG	G	G	G
x_3	VG	G	G	G	MG	MG	G
x_4	G	MG	G	MG	VG	G	G
x_5	G	MG	G	G	G	VG	G

Table V. Evaluation for $R(t_2) = 2013$

Step 5: Aggregating all the intuitionistic fuzzy decision matrices $R(t_i)$ at different years into an aggregated intuitionistic fuzzy decision matrix R.

We suppose that the weight vector of the years is monotonic increasing $(\delta(t_1), \delta(t_2), \delta(t_3))^T = (0.17,\ 0.33,\ 0.50)$. The aggregated intuitionistic fuzzy decision matrix R is determined by using DIFWA operator as in Equation (8):

$$R = \begin{bmatrix} (0.717, 0.173, 0.110) & (0.585, 0.315, 0.100) & (0.755, 0.141, 0.104) & (0.629, 0.267, 0.104) & (0.654, 0.245, 0.101) & (0.786, 0.112, 0.102) & (0.743, 0.151, 0.106) \\ (0.676, 0.218, 0.106) & (0.700, 0.200, 0.100) & (0.676, 0.218, 0.106) & (0.849, 0.112, 0.039) & (0.685, 0.214, 0.101) & (0.685, 0.214, 0.101) & (0.685, 0.214, 0.101) \\ (0.776, 0.120, 0.104) & (0.743, 0.151, 0.106) & (0.676, 0.218, 0.106) & (0.733, 0.159, 0.108) & (0.619, 0.180, 0.101) & (0.585, 0.315, 0.100) & (0.685, 0.214, 0.101) \\ (0.720, 0.178, 0.102) & (0.640, 0.257, 0.103) & (0.676, 0.218, 0.106) & (0.697, 0.189, 0.114) & (0.849, 0.112, 0.039) & (0.743, 0.151, 0.106) & (0.676, 0.218, 0.106) \\ (0.743, 0.151, 0.106) & (0.640, 0.257, 0.103) & (0.743, 0.151, 0.106) & (0.700, 0.200, 0.100) & (0.720, 0.178, 0.102) & (0.849, 0.112, 0.039) & (0.743, 0.151, 0.106) \end{bmatrix}.$$

Step 6: Calculating the distance measures and the closeness coefficient of each candidate.

We consider that $\alpha_i^+ = (1, 0, 0)$ $(i = 1,\ 2, \ldots, 5)$ and $\alpha_i^- = (0, 1, 0)$ $(i = 1,\ 2, \ldots, 5)$. The IFIS $d(x_i, \alpha^+)$ and the IFNIS $d(x_i, \alpha^-)$ are calculated by using Equations (10) and (11) as in Table VII.

The closeness coefficients of the candidates are calculated by using Equation (12) as follows:

$c(x_1) = 0.726$, $c(x_2) = 0.719$, $c(x_3) = 0.732$, $c(x_4) = 0.741$, $c(x_5) = 0.753$.

Step 7: Ranking the candidates and offering of the best candidate for promotion.

Ranking of the candidates with respect to their closeness coefficients is $x_5 > x_4 > x_3 > x_1 > x_2$. According to these ranks, the best candidate is x_5 and he/she is offered for promotion.

6.1 *Sensitivity analysis*

A sensitivity analysis is performed using different weights for years in order to see if the ranking changes. Five different cases in which the weights of years are given as follows are applied in the example and the obtained rankings are presented in Figure 2.

Table VI.
Evaluation for $R(t_3) = 2014$

	a_1	a_2	a_3	a_4	a_5	a_6	a_7
x_1	VG	MG	G	G	G	VG	VG
x_2	MG	G	MG	VVG	G	G	G
x_3	VG	VG	MG	VG	MG	MG	G
x_4	G	G	MG	VG	VVG	VG	MG
x_5	VG	G	VG	G	G	VVG	VG

Table VII.
Distance measures for candidates

Candidates	x_1	x_2	x_3	x_4	x_5
IFIS, $d(x_i, \alpha^+)$	0.302	0.309	0.296	0.283	0.272
IFNIS, $d(x_i, \alpha^-)$	0.803	0.791	0.807	0.810	0.830

Case 1: $(\delta(t_1), \delta(t_2), \ \delta(t_3))^T = (1/6, \ 2/6, \ 3/6)$
Case 2: $(\delta(t_1), \delta(t_2), \ \delta(t_3))^T = (1/3, \ 1/3, \ 1/3)$
Case 3: $(\delta(t_1), \delta(t_2), \ \delta(t_3))^T = (3/6, \ 2/6, \ 1/6)$
Case 4: $(\delta(t_1), \delta(t_2), \ \delta(t_3))^T = (1/6, \ 1/6, \ 4/6)$
Case 5: $(\delta(t_1), \delta(t_2), \ \delta(t_3))^T = (0, \ 0, \ 1)$

According to Figure 2, case 1 shows the current situation and ranking. In case 2, we assume that the weights of years are equal. The ranking of the candidates change utterly and the best one is fourth candidate. In case 3, we assume that the weights of years are monotonic decreasing. The ranking of the second and fifth candidates change their orders and the best one is the same comparing case 2. In case 4, we assume that the weights of first and second years are equal and the weight of the third year is increasing. Orders in case 4 are similar to those in case 1, the third and the first candidates change their orders. In case 5, we assume that years 2012 and 2013 do not have any weight. In other words, we consider that the problem is not dynamic and candidates are evaluated with respect to their current performance. In this case, order of candidates change utterly and fifth one is the best candidate.

In the lights of all results, fourth and fifth candidates share the first choice for promotion. Since the decision-making group has assumed that the weight of years are monotonically increasing, we should consider the cases 1, 4, and 5. Consequently, the fifth candidate emerges as the best one for promotion according to these cases.

6.2 Discussion

Examination of the given numerical example and the foregoing sensitivity analysis suggests that the proposed integrated dynamic model enables the evaluation of candidate performances nominated for the vacant position within an organization for a few years period addressing the personnel promotion problem. According to results, selection process for the best candidate is influenced by the required attributes for the vacant position and their weight, weight of years, performance inclination of the candidates throughout the years and assessments of the candidates by decision-making group. If the decision-making group expects an increasing performance from the candidates, they determine the weights of years as monotonic increasing. On the other hand, the group of decision makers can take into account that the weights of years are equally important or monotonically decreasing with respect to the problem structure and the required qualifications. All of them play a significant role on in the ranking process of the candidates.

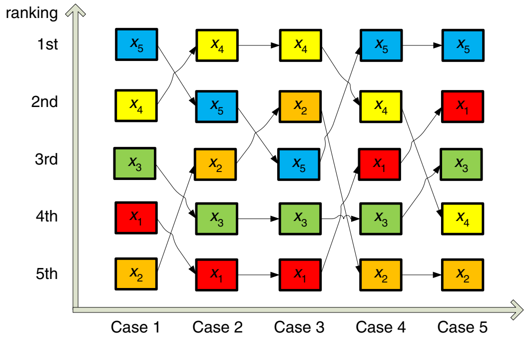

Figure 2.
The obtained rankings of sensitivity analysis

An important point to note in the sensitivity analysis is that the best candidate came out as the fifth one in cases 1 and 5. Although the problem was assumed to be dynamic and the weights of years are monotonically increasing in case 1, the candidates are evaluated for only the last year in case 5, the problem was found to be not dynamic. In both cases, the first and fifth candidates are the same; however, the others' orders are different. This incidence demonstrates that in order to obtain accurate rankings in personnel promotion problem candidates should be evaluated considering the last few years, instead of only the last year of their employment.

7. Conclusion

Personnel promotion is a strategic decision-making problem for an organization. In this study, personnel promotion problem is defined for the first time as a MADM problem in the literature and an integrated dynamic MADM approach based on A-IFS is proposed for solving this problem. The proposed model allows the decision-making group the opportunity to evaluate personnel under uncertain conditions, using linguistic terms for not only the current or last performance, but also past performance of candidates. In the model, AHP technique is used to calculate the weights of attributes and DIFWA operator is used to aggregate evaluations by using intuitionistic fuzzy numbers at different years. The applicability of the model has been demonstrated on the numerical example provided. A sensitivity analysis has been constructed to demonstrate the efficiency of this model. The study has found that the rankings of the candidates and the selection of the most appropriate selection depends primarily on the weights of years. Therefore, we conclude that candidates subject to a personnel promotion problem should be evaluated for each year of their employment separately, indicating that the problem should be viewed as having a dynamic structure.

In future studies, data envelopment analysis can be integrated with the proposed MADM model for solving dynamic personnel promotion problem, in order to have the additional benefit of measuring the efficiency of decision making. Moreover, alternative dynamic operators can be utilized to aggregate evaluations for different years to obtain a variety of results. The dynamic approach we used are adequate for problems in which decision information are collected based on multiple years such as investment decisions, supplier selection, personnel evaluation for conduct grade.

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