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Support managers' selection using an extension of fuzzy TOPSIS

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ABSTRACT

Considering the contemporary business settings, managers' role is more than essential to the viability and further development of an organization. Managers should possess such skills in order to effectively cope with the competition. In this respect, selecting managers based on their skills can lead to a competitive advantage towards the achievement of organizational goals. Highlighting the complexity of the selection process, this study proposes a multicriteria approach based on fuzzy Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) for group decision making. Three new concepts are introduced, namely the relative importance of the decision makers per criterion, the similarity-proximity degree among the decision makers and the veto thresholds, in an effort to better describe the problem and support the process. An empirical application validates the proposed approach for the selection of a middle level manager in a large IT Greek firm.

1. Introduction

The current financial crisis is the biggest one since the Great Depression. At global level, main sectors such as transportation, construction and car industry are radically affected by this recession. As a consequence, organizations and employees face the risk of bankruptcy and layoffs respectively. Under these circumstances, organizations are now called to secure their viability and retain their financial figures in the short term. In certain occasions, even in the frame of this crisis, opportunities still exist and their identification may lead to business development.

It is a clear fact that every organization's management system defines and directs its present and future, in particular under the aforementioned present circumstances. Management policies, processes, tools and structures play a critical role on how to exploit the opportunities and avoid the threats.

Above all, people that apply management have the key role. Managers at every level (tactical, operational and strategic) are those who design, develop, lead the implementation and assess the policies, processes, tools and structures. Managers shoulder the responsibility of an organization's success. Managers' decisions determine the development and sustainability or the failure and collapse of an organization.

Thus, it is an essential parameter for managers to have the necessary knowledge and skills in order to deal with the challenges of the contemporary business settings. Knowledge and skills as outputs of formal education, experience or personal characteristics comprise the basis for proper management behaviors.

Organizations that are administered by high quality managers have a competitive advantage as a result of the following three interconnected theories and hypotheses, (a) the resource-based view of an organization (Barney, 1991), according to which the basis for competitive advantage lies primarily in the resources it possesses; (b) the assumption that people are the most important resource for an organization, since human capital cannot be imitated and copied by the competitors (on the contrary technology and systems can) and (c) the hypothesis that managers are the most important of the human resources, being those who make the decisions, plan the strategies and manage the non-managerial personnel.

Improved management skills can be achieved through training and development programs inside an organization, as well as through experience in practice. Nevertheless, the initial and decisive step is the selective selection of those managers that possess at a minimum extent a number of contemporary management skills.

Taking into account the above mentioned, the aim of this paper is to propose a new approach towards managers' selection problem. Highlighting the complexity of this problem, we consider its multidimensions. Multicriteria decision making (MCDM) methods and fuzzy logic ideally cope with it, given that they incorporate many criteria at the same time, each of them assigned to different importance level. Also, fuzzy logic has the potential to reflect at a very satisfactory degree the vague – most of the times – preferences of the decision makers (DMs).

The rest of the paper is organized as follows: In the next section, comments on the recent literature are summarized as concerns the

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human resources selection problem. Given the limitations and deficiencies of the current approaches, Section 3 provides the basic concepts of fuzzy logic and TOPSIS multicriteria decision support method, based on which a new approach is presented in Section 4, supporting the decision making on managers' selection. In Section 5, a real-life application is demonstrated while conclusions and potential future steps are discussed in Section 6.

2. Recent literature on human resource selection problem

Many scholars have dealt with the human resource selection problem from the decision science point of view. Tools and techniques from operational research and artificial intelligence fields have been used to cope with this specific decision problem. Fuzzy sets and numbers, expert systems, artificial neural networks and multicriteria decision analysis techniques lie among them. Based on a critical perspective of the most recent academic studies, shown in Table 1, are the main comments that constitute the cornerstone on which the proposed approach is based.

Approximately half of the reviewed studies use fuzzy numbers (through linguistic variables) to reflect the performance of the alternatives in the specified criteria. The studies that do not use fuzzy numbers (a) are based on expert systems and artificial neural networks techniques that produce decision rules using the knowledge from data repositories; (b) consider that the DMs possess full information and can precisely evaluate the performance of the alternatives in the criteria; (c) are based on the scores of different tests which alternatives undergo without taking into consideration other evaluation criteria.

When expert systems, if-then rules and neural networks are used, it is doubtful whether the input data can predict the future performance of an employee at a satisfactory and reliable degree. Examples of such data are the ones related to age (Drigas, Kouremenos, Vrettos, Vrettaros, & Kouremenos, 2004), physical skills (Storey Hooper, Galvin, Kilmer, & Liebowitz, 1998), graduation university (Chien & Chen, 2008).

The majority of the reviewed studies do not consider group environment in their analysis, although the authors of this paper believe that group decision making is an indispensable characteristic for a comprehensive description of the problem. A "single DM" approach is justified in cases in which "experience" and former knowledge are used to produce decision rules or in cases that scores in a number of tests define the performance of the alternatives during the selection process. When multicriteria decision analysis techniques are used, the approach to consider one single DM lacks completeness.

About half of the reviewed studies propose generic methods that can apply not only to the human resource selection problem but many other decision problems. These studies apply their methods to simple illustrative examples, using indicative selection criteria. In this respect, they do not valid their approaches into real-life business environments, in which specified and well determined selection criteria should be taken into account. In particular, managers' selection problem requires the definition of a solid framework under which appropriate selection criteria should be assigned.

The following conclusions are drawn from the previous analysis.

(a) There is a lack of a rounded approach that bears in mind the pivotal parameters that describe the human resource selection as a decision problem. These parameters are
(b) Group decision making environment.
(c) The specific preferences and priorities of each DM.
(d) The educational background, knowledge and position of each DM.
(e) The vagueness and fuzziness of available information and the uncertainness of the DMs.
(f) An explicit framework under which selection criteria are determined.

Based on the aforementioned, there is a clear need to define a comprehensive method in order to describe every critical parameter of the problem and adequately support the decision making process.

3. Preliminaries

3.1. Fuzzy logic

Most real world decision problems take place in a complex environment where conflicting systems of logic, uncertain and imprecise knowledge, and possibly vague preferences have to be considered. To face such complexity, the use of specific tools, techniques, and concepts which allow the available information to be represented with the appropriate granularity is believed as crucial. Particularly, fuzzy set theory can ideally cope with this kind of problems.

3.2. Fuzzy sets

Let X be a collection of objects called a universal set. Every other collection of objects will be subset of X. To explain the transition from regular sets, also called crisp sets, to fuzzy sets we start with crisp subsets of X. Let Abe a subset of X. For each x in X we know whether x belongs or does not belong to A. Define a function on X whose values are zero or one as follows: (a) the value of the function at x is one if x is a member of A; and (b) the value is zero if x does not belong to A. We write this function as $A(x) = 1$ if x is in A and $A(x) = 0$ otherwise. This function is called the characteristic function on and any such function, whose values are either zero or one, defines a crisp subset of X.

Fuzzy sets generalize the characteristic function in allowing all values between zero and one. A fuzzy subset F of X is defined by its membership function (a generalization of the characteristic function), also written $F(x)$, whose values can be any number in the interval $[0,1]$. The value of $F(x)$ is called the grade of membership of x in fuzzy set F and is often denoted by $\mu(x)$. If $\mu(x)$ is only zero or one, then we get the characteristic function of a crisp, non-fuzzy, set F. Now suppose we have $\mu(x)$ taking on values in $[0,1]$ besides just zero and one. We say x belongs to F if $\mu_F(x) = 1$, x does not belong to F when $\mu_F(x) = 0$, and x is in F with membership $\mu_F(x)$ if $0 < \mu_F(x) < 1$. The universal set always has $\mu_X(x) = 1$ for all x in X, and the empty set is described by its membership function always zero [$\mu_0(x) = 0$ for all x in X]. Crisp sets are considered special cases of fuzzy sets when membership values are always 0 or 1 (Siler & Buckley, 2005).

3.3. Fuzzy numbers

Fuzzy numbers represent a number of whose value we are somewhat uncertain. They are a special kind of fuzzy set whose members are numbers from the real line, and hence are infinite in extent. Fuzzy numbers may be of almost any shape (though conventionally they are required to be convex and to have finite area), but frequently they will be triangular (piecewise linear), s-shape (piecewise quadratic) or normal (bell shaped). Fuzzy numbers may also be basically trapezoidal, with an interval within which the membership is 1; such numbers are called fuzzy intervals. Fuzzy intervals may have linear, s-shape or normal "tails", the increasing and decreasing slopes (Siler & Buckley, 2005). Assume that

Table 1
Recent studies on the personnel selection problem.

Proposed by	Fuzziness	Techniques	Empirical application	Illustrative example	Group decision making	Main criteria
Liang and Wang (1992)	Yes	Fuzzy numbers	No	Personnel placement	Yes	General aptitude, leadership, self-confidence, professional knowledge
Carlsson et al. (1997)	No	OWA Operators	Doctoral student selection	No	Yes	Research interests (fit in research groups, on the frontier of research, contributions), academic background (university, grade average, time for acquiring degree)
Storey Hooper et al. (1998)	No	Expert Systems	Field grade officer selection for advanced training	No	No	Hierarchical grade, military education level, civilian education level, official photograph, height and weight, assignment history, officer efficiency report evaluations
McIntyre et al. (1999)	No	Analytic Hierarchy Process	Selection of division director in a University department	No	No	Administration, Teaching, Research, Service, Industry
Chen (2000)	Yes	Fuzzy TOPSIS	No	System analysis engineer selection in a software company	Yes	Emotional steadiness, oral communication skill, personality, past experience, self-confidence
Karsak (2000)	Yes	Fuzzy Multiple Objective Programming	No	Personnel Selection for an expatriate position	No	Personality assessment, leadership excellence, excellence in oral communication skills, past experience, computer skills, fluency in foreign language, aptitude test score, annual salary request
Butkiewicz (2002)	Yes	Fuzzy numbers	No	Staff selection in a tourism agency	No	Education, working knowledge, geographical knowledge, apparition, computer skills, know-how of office equipment, serenity, responsibility, patience, competence, ability of good discussion
Cho and Ngai (2003)	No	Discriminant analysis, decision trees, artificial neural networks	Insurance sales agents selection	No	No	Sex, date of birth, nationality, academic level, number of dependants, job position, work experience, management experience, total amount of insurance sold, eligibility to sell particular products, commencement date, termination date, previous job nature, previous annual income
Yeh (2003)	No	Total sum (TS) method, simple additive weighting (SAW) method, weighted product (WP) method, TOPSIS	Scholarship student selection	No	No	Community services, sports/hobbies, work experience, energy, communication skills, attitude to business, maturity, leadership
Drigas et al. (2004)	Yes	Expert systems, Neuro-Fuzzy techniques	Unemployed matching	No	No	Age, education, additional education (training), previous employment (experience), foreign language (English), computer knowledge
Huang et al. (2004)	Yes	Fuzzy Neural Networks, Fuzzy Analytic Hierarchy Process, simple additive weighting (SAW) method	Middle manager selection	No	Yes	Capability trait, motivational trait, personality trait, conceptual skill, interpersonal skill, technical skill
Chen and Cheng (2005)	Yes	Fuzzy numbers	No	IS project manager recruitment	Yes	Analysis and design, Programming, Interpersonal skills, business knowledge, IS environment knowledge, IS applications knowledge
Jereb et al. (2005)	No	Expert Systems, decision rules	No	Personnel selection	No	Education, relational skills, working skills, performance, leadership, working approach, other (self-confidence, emotional stability, self control)
Saghafian and Hejazi (2005)	Yes	Fuzzy TOPSIS	No	University professor hiring	Yes	Publications and researches, teaching skills, practical experiences in industries and corporations, past experiences in teaching, teaching discipline
Seol and Sarkis (2005)	No	Analytic Hierarchy Process	No	Internal auditor selection	No	Technical skills, analytic/design skills, appreciative skills, personal skills, interpersonal skills, organizational skills
Shih et al. (2005)	No	Nominal group technique, Analytic Hierarchy Process, TOPSIS, Borda's function	On-line manager recruitment	No	Yes	knowledge tests (including language test, professional test, and safety rule test), skill tests (including professional skills and computer skills), and interviews (including panel interview and one-to-one interviews)
Baykasoglu et al. (2007)	Yes	Fuzzy multiple objective mathematical programming, simulated annealing	No	Project team members selection	No	Communication skills, technical expertise, problem solving ability, decision making skills, available time period, salary request

Table 1 (*continued*)

Proposed by	Fuzziness	Techniques	Empirical application	Illustrative example	Group decision making	Main criteria
Golec and Kahya (2007)	Yes	Fuzzy numbers, fuzzy rules	No	Employee evaluation and selection	No	Communication skills, personal traits and self-motivation, interpersonal skills and ability to sell self and ideas, decision making ability, technical knowledge base skills, career development aspiration, management skills
Mehrabad and Brojeny (2007)	No	Expert Systems	intelligent selection in an R&D organization	No	No	Educational level, work experience management experience
Shih et al. (2007)	No	Group TOPSIS	No	On-line manager recruitment in a local chemical company	Yes	Knowledge tests (language test, professional test, safety rule test), skill tests (professional skills, computer skills), interviews
Chien and Chen (2008)	No	Decision trees, decision rules	Engineers and managers selection in a semiconductor company	No	No	Age, gender, marital status, educational background, work experience, school tiers, recruitment channel
Dağdeviren (2008)	Yes	Analytic Network Process (ANP), TOPSIS	Electronics engineer selection in a manufacturing company	No	No	Ability to work in different business units, past experience, team player, fluency in a foreign language, strategic thinking, oral communication skills, computer skills
Mahdavi et al. (2008)	Yes	Fuzzy TOPSIS	No	System analyst selection in a software company	Yes	Emotional steadiness, oral communication skill, personality, past experience, self-confidence
Güngör et al. (2009)	Yes	Fuzzy Analytic Hierarchy Process	No	Personnel selection	No	General work factors (work experience, foreign language, bachelor degree, master degree, analytical thinking, basic comp. skill), complimentary work factors (decision making, working in teams, effective time using, determination of goal, long life learning, willingness), individual factors (core ability, culture, age, appearance, oral, written comm.)
Saremi et al. (2009)	Yes	Fuzzy TOPSIS	TQM consultant selection	No	Yes	Knowledge of business (strategies, process, markets), relevant experience (TQM project, similar firms), technical skills (people, system, specific abilities), management skills (organization, economic stability, acceptable insurance, certificates), implementation cost

triangular and s-shaped fuzzy numbers start rising from zero at $x = a$; reach a maximum of 1 at $x = b$; and decline to zero at $x = c$. Then the membership function $\mu(x)$ of a triangular, piecewise linear, fuzzy number is given by

$$\mu(x) = \begin{cases} 0, & x < a \\ \frac{x-a}{b-a}, & a \leqslant x < b \\ \frac{x-c}{b-c}, & b \leqslant x < c \\ 0, & x > c \end{cases} \tag{1}$$

3.4. TOPSIS

The Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) was firstly proposed by Hwang and Yoon (1981). The approach is based on a synthesizing criterion like MAUT (see Figueira, Greco, & Ehrgott, 2005) and AHP (Saaty, 1980). The main concept of this method is that the most preferred alternative should have the shortest distance from the positive ideal solution (PIS) and the longest distance from the negative ideal solution (NIS). PIS is the one that maximizes the benefit criteria and minimizes the cost criteria, while the NIS maximizes the cost criteria and minimizes the benefit criteria. In traditional TOPSIS, the weights of the criteria and the ratings of alternatives are known precisely and are treated as crisp numerical data. However, under many conditions crisp data are inadequate to model real-life decision problems; in addition, perfect knowledge is not easily acquired. Unquantifiable, incomplete and non-obtainable information make precise judgment impossible. Therefore, fuzzy TOPSIS has been proposed where criteria weights and alternative ratings are given by linguistic variables that are expressed by fuzzy numbers.

4. Proposed approach

As shown in Table 1, TOPSIS has been used in a number of human resource selection problems. In general, TOPSIS method is easy to understand and to implement. These issues are of fundamental importance for a direct field implementation of the method by practitioners. Moreover, it allows the straight linguistic definition of importance and ratings under each criterion, without the need of cumbersome pairwise comparisons and the risk of inconsistencies (Bottani & Rizzi, 2006). Also, according to Zanakis, Solomon, Wishart, and Dublish (1998), the performance is slightly affected by the number of alternatives and rank discrepancies are amplified to a lesser extent for increasing values of the number of alternatives and the number of criteria. In this paper, a new technique, based on fuzzy TOPSIS for group decision making is considered, incorporating three new concepts, namely the relative importance of the DMs per criterion, the similarity-proximity degree among the DMs and the veto thresholds.

4.1. The proposed algorithm

The steps of the proposed method can be described as follows.
(a) *Formation of the decision making group*

Managers' selection is a critical task for an organization, in particular when the organization demands immediate results in the short term under unfavorable circumstances. In this process, more rational decisions are made by a group of people rather than by a single person. Usually, experts from different departments along with senior managers and organizational psychology experts form the group of the DMs. The decision on the evaluators' group formation can be made by the Director of the HR department or directly by the CEO.

(b) *Definition of a finite set of relevant criteria*

Criteria should be defined that cover the requirements of the DMs and relate to the specific job description. The process should take into consideration the market, in which the firm operates, the type and the hierarchical level of the position to be covered. For example, different criteria should be considered for salesmen, IT systems developers or factory workers. As the focus of this study is on managers' selection, the proposed set of criteria consists of ten "soft" managerial skills and two "technical" managerial skills that every manager at every hierarchical level should possess. The main characteristics of the "soft" skills are that (a) they develop over time, (b) they are transferable, (c) each one consists of an interconnected set of behaviors, the practice of which validates the possession of the skill. The managerial skills to be considered are (1) creativity/innovation, (2) problem solving/decision making, (3) conflict management/negotiation, (4) empowerment/delegation, (5) strategic planning, (6) specific presentation skills, (7) communication skill, (8) team management, (9) diversity management, (10) self-management, (11) professional experience and (12) educational background. The last two "technical" skills are related to the real knowledge a manager has acquired through experience and education and not only the typical qualifications, like years of experience or number of diplomas obtained.

(c) *Choice of appropriate values for the linguistic variables and respective scales*

A linguistic variable is a variable whose values are linguistic terms, i.e. words or sentences (Siler & Buckley, 2005). For example, communication skill is a linguistic variable when its linguistic values can be "poor", "fair" or "good". Each linguistic value can be represented by a fuzzy number which can be assigned to a membership function. In our approach, we consider triangular fuzzy numbers to be associated to the linguistic values and scales of 11 points for the ratings. The linguistic values picture the importance of the DMs, the importance of the criteria (see next steps) as well as the ratings of the alternatives on the criteria. Table 2 shows the respective values in an 11-point scale.

(d) *Definition of relative importance of the DMs in each criterion*

Each DM has a unique educational background and field of expertise compared to the others'. This leads to different level of knowledge over different aspects of a specific job requirements. We consider that the managers' selection problem can be described and supported better if DMs' opinions have different importance among the several criteria, reflecting their expertise and the nature of the criterion. For example, a consultant in the field of organizational psychology is expected to be assigned to a greater importance for a "soft" criterion, like team management, than a technical manager. The relative importance of the DMs, in practice, can be made by the Director of the HR department or an external consultant.

(e) *Definition of criteria importance*

Each DM should assign the importance of each criterion, according to the requirements and the expectations from the position to be filled. It is not uncommon that two DMs have conflicting views on the importance of a criterion, one considering it very important while the other does not. TOPSIS method provides the possibility to the DMs to assign importance simply using the values of the linguistic variables, without the need of any other specific weighting method. This makes the whole process easy to understand and follow.

(f) *Determination of the veto thresholds*

In order to simulate the reality and the behavior of the DMs, veto threshold should be defined by every DM.

In outranking methods, veto threshold indicates situations when the difference between two alternatives with respect to one specified criterion negates any possible outranking relationship indicated by other criteria. This means that when an alternative is significantly bad on one criterion compared to another alternative, it cannot outrank the other alternative, regardless its performance on the other criteria.

We "borrow" this concept, allowing each DM to assign a veto to each criterion. In this respect, veto expresses the power of every DM to negate the selection of an alternative as a solution, when this alternative performs worse than the veto set on the respective criterion.

In reality, though, we may face situations when all alternatives perform below a veto. In this respect, we propose that the preferred alternative is the one with the higher cumulative distance from the vetos of all criteria.

(g) *Determination of the similarity and proximity degrees*

This is a concept introduced in an effort to describe and eliminate situations in which one or more DMs are biased for or against a candidate. In these situations, the DM(s) may rate much more or much less than the other DMs and affect the final result. In order to avoid this phenomenon, two new measures are introduced, the similarity and proximity degrees among the DMs. The similarity degree refers to the "distance" between the ratings of two DMs for the same alternative on a criterion, while the proximity degree refers to the closeness of one's rating to the mean of the ratings for the same alternative on a criterion. Considering the maximum distance (minimum similarity) as in the relation (2), we have

$$\bar{x}(\sigma_{10}) - \bar{x}(\sigma_0) = d\sigma_{max} \tag{2}$$

where for a triangular fuzzy number $u = (l, m, n)$ with a membership function

$$\mu(x) = \begin{cases} 0, & x < l \\ \mu^L(x), & l \leqslant x < m \\ \mu^R(x), & m \leqslant x < n \\ 0, & x > n \end{cases} \tag{3}$$

is

$$\bar{x}(u) = \frac{\int_l^m x\mu^L(x)dx + \int_m^n x\mu^R(x)dx}{\int_l^m \mu^L(x)dx + \int_m^n \mu^R(x)dx} \tag{4}$$

using the centroid defuzzification method.

If m is the number of alternatives, n, the number of criteria and K, the number of DMs, with $i = 1,2,\ldots,m$, $j = 1,2,\ldots,n$, $k = 1,2,\ldots,K$

Table 2
Scale for defining the importance and rating the alternatives.

Importance		Rating	
Linguistic value	Fuzzy number	Linguistic value	Fuzzy number
Definitely low	$\omega_0 = (0,0,0.1)$	Definitely poor	$\sigma_0 = (0,0,1)$
Extremely low	$\omega_1 = (0,0.1,0.2)$	Extremely poor	$\sigma_1 = (0,1,2)$
Very low	$\omega_2 = (0.1,0.2,0.3)$	Very poor	$\sigma_2 = (1,2,3)$
Low	$\omega_3 = (0.2,0.3,0.4)$	Poor	$\sigma_3 = (2,3,4)$
Medium low	$\omega_4 = (0.3,0.4,0.5)$	Medium poor	$\sigma_4 = (3,4,5)$
Medium	$\omega_5 = (0.4,0.5,0.6)$	Fair	$\sigma_5 = (4,5,6)$
Medium high	$\omega_6 = (0.5,0.6,0.7)$	Medium good	$\sigma_6 = (5,6,7)$
High	$\omega_7 = (0.6,0.7,0.8)$	Good	$\sigma_7 = (6,7,8)$
Very high	$\omega_8 = (0.7,0.8,0.9)$	Very good	$\sigma_8 = (7,8,9)$
Extremely high	$\omega_9 = (0.8,0.9,1)$	Extremely good	$\sigma_9 = (8,9,10)$
Definitely high	$\omega_{10} = (0.9,1,1)$	Definitely good	$\sigma_{10} = (9,10,10)$

the respective indexes, then, we define the similarity degree as the fraction

$$\frac{d\sigma_{max} - \left|\bar{x}\left(\widetilde{S}_{ijk_1}\right) - \bar{x}\left(\widetilde{S}_{ijk_2}\right)\right|}{d\sigma_{max}} > \delta \tag{5}$$

$\forall j = 1,2,\ldots,n,\ \forall i = 1,2,\ldots,m,\ \forall k_1,k_2 = 1,2,\ldots,K,\ k_1 \neq k_2.$

$\delta \in [0,1]$ is the value under which the similarity degree is considered unacceptable and the whole process of assigning ratings must be repeated.

In addition, we can define the mean of the ratings of all DMs for the alternative i on the criterion j as

$$mean_{ij} = \frac{1}{k}\sum_{k=1}^{K} \bar{x}\left(\widetilde{S}_{ijk}\right) \tag{6}$$

and the proximity degree can be the fraction

$$\frac{d\sigma_{max} - \left|\bar{x}(\tilde{s}_{ijk}) - mean_{ij}\right|}{d\sigma_{max}} > \varepsilon \tag{7}$$

$\forall j = 1,2,\ldots,n,\ \forall i = 1,2,\ldots,m,\ \forall k = 1,2,\ldots,K.$

$\varepsilon \in [0,1]$ is the value under which the proximity degree is considered unacceptable and the whole process of assigning ratings must be repeated.

(h) *Calculation of aggregated values*

Let us define the following variables:

$\widetilde{Z}_{jk} = \left(Z^l_{jk}, Z^m_{jk}, Z^u_{jk}\right)$, the fuzzy number that represents the importance of the kth DM on the jth criterion.

$\widetilde{W}_{jk} = \left(W^l_{jk}, W^m_{jk}, W^u_{jk}\right)$, the fuzzy number that represents the importance of the jth criterion according to the kth DM.

$\tilde{t}_{jk} = \left(t^l_{jk}, t^m_{jk}, t^u_{jk}\right)$, the fuzzy number that represents the veto threshold of the jth criterion according to the kth DM.

$\tilde{s}_{ijk} = \left(s^l_{ijk}, s^m_{ijk}, s^u_{ijk}\right)$, the fuzzy number that represents the rating of the ith alternative on the jth criterion according to the kth DM.

In this step, the aggregation of all values provided by the DMs is performed. This refers to the ratings of the alternatives, the importance of the criteria and the veto thresholds. The concept behind the aggregation is to take into consideration the relative importance of the DMs. In this respect, the centroid defuzzification method will be used to produce scalars from fuzzy $\widetilde{Z}_{jk}$ numbers.

The centroid of the importance of the kth DM on the jth criterion can be expressed as $\bar{x}(\widetilde{Z}_{jk})$, thus the weighted importance of the kth DM on the jth criterion is

$$\bar{x}(\widetilde{Z}_{jk})^W = \frac{\bar{x}(\widetilde{Z}_{jk})}{\sum_{k=1}^{K}\bar{x}(\widetilde{Z}_{jk})} \tag{8}$$

The lower bound of the weighted rating of the ith alternative on the jth criterion according to the kth DM is then

$$s^{lW}_{ijk} = S^l_{ijk} \times \bar{x}(\tilde{z}_{jk})^W \tag{9}$$

The sum for all DMs is the aggregated value of the lower bound of the ith alternative's rating on the jth criterion

$$x^l_{ij} = \sum_{K=1}^{K} S^{lW}_{ijk} \tag{10}$$

Similarly, x^m_{ij} and x^u_{ij} can be calculated, as well as the aggregated importance $\tilde{w}_j = \left(w^l_j, w^m_j, w^u_j\right)$ and the aggregated veto threshold $\tilde{t}_j = \left(t^l_j, t^m_j, t^u_j\right)$ of the jth criterion.

(i) *Establishment of the fuzzy decision matrix*

The fuzzy decision matrix is presented as follows:

$$\begin{bmatrix} \tilde{x}_{11} & \cdots & \tilde{x}_{1n} \\ \vdots & \ddots & \vdots \\ \tilde{x}_{m1} & \cdots & \tilde{x}_{mn} \end{bmatrix} \tag{11}$$

$$\widetilde{W}_j = [\tilde{w}_1, \tilde{w}_2, \ldots, \tilde{w}_n] \tag{12}$$

$$\widetilde{T}_j = [\tilde{t}_1, \tilde{t}_2, \ldots, \tilde{t}_n] \tag{13}$$

with $\tilde{x}_{ij} = \left(x^l_{ij}, x^m_{ij}, x^u_{ij}\right), \widetilde{W}_j = \left(w^l_j, w^m_j, w^u_j\right)$ and $\tilde{t}_{ij} = \left(t^l_j, t^m_j, t^u_j\right)$ having been calculated as shown on step (h).

(j) *Construction of the normalized fuzzy matrix*

Applying the appropriate operator to each element of the fuzzy decision matrix, we obtain the normalized fuzzy matrix. In this respect, every triangular fuzzy number lies between 0 and 1. The matrix can be expressed as

$$\widetilde{R} = [\tilde{r}_{ij}]_{m\times n} \tag{14}$$

and

$$\widetilde{T}^R = [\tilde{t}^R_j]_{1\times n} \tag{15}$$

is the respective matrix for the veto thresholds, with

$$\tilde{r}_{ij} = \left(\frac{x^l_{ij}}{c^*_j}, \frac{x^m_{ij}}{c^*_j}, \frac{x^u_{ij}}{c^*_j}\right), \quad j \in B$$

And

$$\tilde{t}^R_j = \left(\frac{t^l_j}{c^*_j}, \frac{t^m_j}{c^*_j}, \frac{t^u_j}{c^*_j}\right), \quad j \in B$$

$c^*_j = \max(\max_i x^u_{ij}, t^u_j)$ if $j \in B$, where B is the set of benefit criteria and

$$\tilde{r}_{ij} = \left(\frac{a^-_j}{x^u_{ij}}, \frac{a^-_j}{x^m_{ij}}, \frac{a^-_j}{x^l_{ij}}\right), \quad j \in C$$

$$\tilde{t}^R_j = \left(\frac{a^-_j}{t^u_j}, \frac{a^-_j}{t^m_j}, \frac{a^-_j}{t^l_j}\right), \quad j \in C$$

$a^-_j = \min(\min_i x^l_{ij}, t^l_j)$ if $j \in C$, where C is the set of cost criteria, following the linear normalization method (see more in Shih, Shyur, & Lee, 2007).

(k) *Construction of the weighted normalized fuzzy matrix*

In this step, we incorporate the importance of each criterion, taking the matrices

$$\widetilde{V} = [\tilde{v}_{ij}]_{m\times n} \tag{16}$$

$j = 1,2,\ldots,n,\ i = 1,2,\ldots,m$ and

$$\widetilde{T}^V = \left[\tilde{t}^V_j\right]_{1\times n} \tag{17}$$

for the veto thresholds, where

$$\tilde{v}_{ij} = \tilde{r}_{ij}(\cdot)\tilde{w}_j \tag{18}$$

and

$$\tilde{t}^V_j = \tilde{t}^R_j(\cdot)\tilde{w}_j \tag{19}$$

(l) *Calculation of the distance of each alternative from the veto threshold defined for each criterion*

In order to calculate the distance of each alternative from the veto threshold defined for each criterion, avoiding also situations of incomparability, we have to compute a scalar from the fuzzy numbers (defuzzification process). Following the centroid method the distance between two fuzzy numbers, u and w can be expressed as $d(u,w) = \bar{x}(u) - \bar{x}(w)$. In this respect, the total distance between an alternative and the veto thresholds of all criteria is given by

$$d_i = \sum_{j=1}^{n} d\left(\tilde{v}_{ij}, \tilde{t}_j^V\right), \quad i = 1, 2, \ldots, m \tag{20}$$

where

$$d\left(\tilde{v}_{ij}, \tilde{t}_j^V\right) = \bar{x}(\tilde{v}_{ij}) - \bar{x}\left(\tilde{t}_j^v\right) \tag{21}$$

(m) *Rank the alternatives*

According to the distance as defined above, the final ranking of the alternatives can be produced. The one with the maximum value of is considered as the best solution.

5. An empirical application

The purpose of the empirical application is to illustrate the use of the suggested method. The experiment was setup upon a real-life decision. The partner organization is Greece's largest multinational provider of telecommunications products, solutions and services. The organization employs specialized and experienced personnel while the managerial staff combines a strong engineering background with contemporary soft skills. Following a mutual agreement, it was decided to apply the proposed selection approach for the hiring of a middle level manager for the position of a Wireless Product Marketing/Presales Engineer. Three final candidates (A1, A2, A3) were qualified through the recruitment phase. Afterwards, the Director of the HR department, as the facilitator of the whole process, concluded to the DMs team as follows: The first DM was the direct supervisor of this post, holding the position of "Systems & Solutions Marketing Manager" (D1). The second DM (D2) was the General Director of the "Subsidiaries Function" of the organization, a headquarters level department. The last DM was the Director of the HR department himself (D3). The evaluation criteria were defined according to the proposed method, being ten "soft" managerial skills and two "technical" skills. The selection methods applied were the screening of the candidates' CVs and two rounds of semi-structured interviews. In addition a case interview was conducted, in order that the DMs retrieve information about the candidates, based on a real business scenario.

Following the proposed approach, the facilitator of the process initially defined the importance degree of each DM. Moreover, each

Table 3
Importance of the DMs on the respective criteria.

Decision makers	Criteria											
	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12
D1	VH	M	VH	M	M	M	M	VH	MH	MH	M	M
D2	MH	VH	M	M	VH	M	M	MH	MH	MH	VH	VH
D3	MH	M	VH	H	ML	VH	VH	VH	MH	MH	ML	ML

Table 4
Assignment of importance to criteria by the DMs.

Decision makers	Criteria											
	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12
D1	M	VH	VH	H	VH	H	H	H	H	VH	M	M
D2	M	MH	MH	H	VH	M	M	H	M	H	EH	EH
D3	EH	H	VH	M	M	EH	EH	EH	VH	M	M	M

Table 5
Assignment of veto to criteria by the DMs.

Decision makers	Criteria											
	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12
D1	F	G	G	F	G	G	MG	F	G	MG	MG	G
D2	VG	MG	G	G	MG	F	MG	F	MG	MG	G	F
D3	F	G	MG	MG	G	G	F	MG	F	G	F	MG

Table 6
Ratings of the alternatives by the DMs.

Decision makers	Alternatives	Criteria											
		C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12
D1	A1	G	G	VG	MG	G	VG	G	VG	G	VG	EG	EG
	A2	DG	MG	MG	G	MG	EG	EG	DG	G	G	G	G
	A3	G	DG	G	G	EG	MG	MG	MG	G	DG	G	G
D2	A1	VG	G	G	F	G	VG	G	G	G	VG	DG	DG
	A2	EG	MG	F	G	G	EG	DG	DG	G	MG	G	G
	A3	G	EG	VG	MG	EG	F	F	G	EG	VG	G	MG
D3	A1	G	G	VG	MG	G	EG	G	G	G	G	DG	DG
	A2	EG	G	F	G	MG	EG	EG	EG	MG	MG	G	G
	A3	VG	EG	VG	G	EG	MG	F	G	EG	VG	G	MG

DM defined the importance degree of and the veto for each criterion. Finally, upon completion of the evaluation, they all assigned scores to each of the three candidates. Tables 3–6 show the linguistic values, based on the 11-point scales, depicted in Table 2.

On the next step, the similarity and proximity degrees were calculated so that the process can be considered valid and unbiased. The facilitator set the similarity degrees δ and the proximity degrees ε to 0.75 both, for every criterion and every alternative. As of the results shown in Tables 7 and 8, the scores satisfied the requirements and the whole process could further proceed.

In this respect, the Fuzzy decision matrix could be constructed (Table 9), taken into consideration Eqs. (8)–(13).

Based on Eqs. (14)–(21), the final ranking of sthe candidates is the one pictured in the Table 10. According to this ranking, candidate 1 (A1) was the preferred one, and finally the selected one for the respective position, having the highest positive distance from the vetos of the criteria.

Table 10
The final ranking of the alternatives.

Ranking	
A1	1.27
A2	1.10
A3	1.02

6. Discussion

The aim of this paper was to support adequately the decision on managers' selection within organizations. Following as principle the resource-based point of view, the assumption that people are the most important resource for an organization and the hypothesis that managers are the most important of the human resources, being those who make the critical decisions, we faced this problem

Table 7
Proximity degrees.

Alternatives	Decision makers	Criteria											
		C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12
A1	D1	0.95	1.00	0.96	0.94	1.00	0.96	1.00	0.91	1.00	0.96	0.95	0.95
	D2	0.91	1.00	0.91	0.88	1.00	0.96	1.00	0.95	1.00	0.96	0.98	0.98
	D3	0.95	1.00	0.96	0.94	1.00	0.92	1.00	0.95	1.00	0.91	0.98	0.98
A2	D1	0.95	0.95	0.88	1.00	0.95	1.00	0.98	0.98	0.95	0.89	1.00	1.00
	D2	0.98	0.95	0.94	1.00	0.89	1.00	0.95	0.98	0.95	0.95	1.00	1.00
	D3	0.98	0.89	0.94	1.00	0.95	1.00	0.98	0.95	0.90	0.95	1.00	1.00
A3	D1	0.95	0.95	0.91	0.95	1.00	0.94	0.88	0.90	0.84	0.87	1.00	0.89
	D2	0.95	0.98	0.96	0.90	1.00	0.88	0.94	0.95	0.92	0.94	1.00	0.95
	D3	0.91	0.98	0.96	0.95	1.00	0.94	0.94	0.95	0.92	0.94	1.00	0.95

Table 8
Similarity degrees.

Alternatives	Decision makers	Criteria											
		C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12
A1	D1–D2	0.88	1.00	0.88	0.83	1.00	1.00	1.00	0.88	1.00	1.00	0.93	0.93
	D1–D3	1.00	1.00	1.00	1.00	1.00	0.89	1.00	0.88	1.00	0.88	0.93	0.93
	D2–D3	0.88	1.00	0.88	0.83	1.00	0.89	1.00	1.00	1.00	0.88	1.00	1.00
A2	D1–D2	0.93	1.00	0.83	1.00	0.86	1.00	0.93	1.00	1.00	0.86	1.00	1.00
	D1–D3	0.93	0.86	0.83	1.00	1.00	1.00	1.00	0.93	0.86	0.86	1.00	1.00
	D2–D3	1.00	0.86	1.00	1.00	0.86	1.00	0.93	0.93	0.86	1.00	1.00	1.00
A3	D1–D2	1.00	0.93	0.88	0.86	1.00	0.83	0.83	0.86	0.78	0.83	1.00	0.86
	D1–D3	0.88	0.93	0.88	1.00	1.00	1.00	0.83	0.86	0.78	0.83	1.00	0.86
	D2–D3	0.88	1.00	1.00	0.86	1.00	0.83	1.00	1.00	1.00	1.00	1.00	1.00

Table 9
Fuzzy decision matrix.

	Criteria					
	C1	C2	C3	C4	C5	C6
A1	(6.30, 7.30, 8.30)	(6.00, 7.00, 8.00)	(6.76, 7.76, 8.76)	(4.71, 5.71, 6.71)	(6.00, 7.00, 8.00)	(7.44, 8.44, 9.44)
A2	(8.40, 9.40, 10.00)	(5.28, 6.28, 7.28)	(4.38, 5.38, 6.38)	(6.00, 7.00, 8.00)	(5.47, 6.47, 7.47)	(8.00, 9.00, 10.00)
A3	(6.30, 7.30, 8.30)	(8.28, 9.28, 10.00)	(6.62, 7.62, 8.62)	(5.71, 6.71, 7.71)	(8.00, 9.00, 10.00)	(4.72, 5.72, 6.72)
Veto	(4.90, 5.90, 6.90)	(5.56, 6.56, 7.56)	(5.62, 6.62, 7.62)	(5.00, 6.00, 7.00)	(5.53, 6.53, 7.53)	(5.44, 6.44, 7.44)
Importance	(0.52, 0.62, 0.72)	(0.58, 0.68, 0.78)	(0.65, 0.75, 0.85)	(0.52, 0.62, 0.72)	(0.63, 0.73, 0.83)	(0.63, 0.73, 0.83)
	C7	C8	C9	C10	C11	C12
A1	(6.00, 7.00, 8.00)	(6.36, 7.36, 8.36)	(6.00, 7.00, 8.00)	(6.67, 7.67, 8.67)	(8.71, 9.71, 10.00)	(8.71, 9.71, 10.00)
A2	(8.28, 9.28, 10.00)	(8.64, 9.64, 10.00)	(5.67, 6.67, 7.67)	(5.33, 6.33, 7.33)	(6.00, 7.00, 8.00)	(6.00, 7.00, 8.00)
A3	(4.28, 5.28, 6.28)	(5.64, 6.64, 7.64)	(7.33, 8.33, 9.33)	(7.67, 8.67, 9.33)	(6.00, 7.00, 8.00)	(5.29, 6.29, 7.29)
Veto	(4.56, 5.56, 6.56)	(4.36, 5.36, 6.36)	(5.00, 6.00, 7.00)	(5.33, 6.33, 7.33)	(5.24, 6.24, 7.24)	(4.82, 5.82, 6.82)
Importance	(0.63, 0.73, 0.83)	(0.67, 0.77, 0.87)	(0.57, 0.67, 0.77)	(0.57, 0.67, 0.77)	(0.59, 0.69, 0.79)	(0.59, 0.69, 0.79)

from a multicriteria perspective. The complexity and importance of the problem call for analytical methods rather than intuitive decisions. Taking into consideration the above mentioned, the aim of this study was to deal with managers' selection problem, proposing a multicriteria decision analysis approach.

The specificity of this problem consists in dealing with imprecise data, difficulties in retrieving information and expressing an explicit opinion. Fuzzy logic is considered ideal to deal with this type of problems. Moreover, this specific problem is closely associated to the DMs. Every DM has particular preferences and demands prerequisites in relation to the profile of the ideal solution. Both above mentioned characteristics were taken into consideration in our approach. Thus, a new approach based on fuzzy TOPSIS was used, introducing a new measurement. This is the veto threshold that reflects the minimum requirements of the DMs from each alternative on each criterion. In addition, the similarity and proximity degrees were introduced in an effort to eliminate biased and unfair judgements of the DMs.

The proposed approach has also practical implications as the empirical study showed in the case of a middle level manager selection, supporting a very sensitive decision in real time.

As a future step to this paper could be the comparison of the proposed approach to other MCDA methods, like TOPSIS, AHP or even more to the outranking methods, such as ELECTRE III and PROMETHEE II.

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