Weighted Fuzzy Group Decision-making in Recruitment

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Abstract

This article deals with group decision making during recruitment of new employees. The importance of correct selection of a candidate during the recruitment is very easy to understand, but not so easy to achieve. Especially in situations where decision-makers have to evaluate large number of different candidates. The proposed approach was created to help decision-makers to find the most suitable candidate by using only vague expressions. Given the uncertainty, subjectivity and ambiguity of human knowledge, the entire approach is based on Fuzzy Set Theory. More specifically on new innovative transformation of fuzzy numbers through α -level cuts. The transformation of fuzzy numbers will be used to taking into account weigh of each member of the decision-making group and the weights will be calculated by using the AHP method. The shape and po-sition of fuzzy numbers play the key role in the transformation. Additionally, the Hamming distance will be used for the final interpretation of the results, thus there is no loss of information caused by defuzzification.

Keywords: α -level, Decision making, fuzzy number, Hamming distance, linguistic scale, Recruitment.

Fuzzy toma de decision grupal ponderada en reclutamiento

Resumen

El artículo trata sobre la toma de decisiones grupales durante la contratación de nuevos empleados. La importancia de la selección correcta de un candidato durante el reclutamiento es muy fácil de entender, pero no tan fácil de lograr. Especialmente en situaciones donde los tomadores de decisiones tienen que evaluar un gran número de candidatos diferentes. El enfoque propuesto se creó para ayudar a los responsables de la toma de decisiones a encontrar al candidato más adecuado utilizando solo expresiones vagas. Dada la incertidumbre, la subjetividad y la ambigüedad del conocimiento humano, todo el enfoque se basa en la teoría de conjuntos difusos. Más específicamente en la nueva transformación innovadora de números difusos a través de cortes de nivel α . La transfor-mación de los números difusos se utilizará para tomar en cuenta el peso de cada miembro del grupo de toma de decisiones y los pesos se calcularán utilizando el método AHP. La forma y la posición de los números difusos juegan un papel clave en la transformación. Además, la distancia de Hamming se utilizará para la interpretación final de los resultados, por lo que no hay pérdida de información causada por la defuzzificación.

Palabras claves: *nivel α , toma de decisiones, número de fuzzy, distancia de Hamming, escala lingüística, reclutamiento.*

1 Introduction

It is generally accepted that an organization's success is closely tied to people it hires. Therefore, it is not a big surprise that the topic of employee selection has attracted great attention from researchers over the years (Breaugh, 2009). As Golec and Kahya (2007) mention, the employee evaluation and selection system are an important problem that can significantly affect the future competitiveness and the performance of an organization. As it is emphasized by Slaughter, Bagger and Li (2006), the attention given to judgment and decision-making research when studying employee selection, especially employer choices among job finalists, should be greater.

The choice of the evaluation approach depends on the kind of the problem and the type of data available (Medasani, Kim and Krishnapuram, 1998). It has been inferred that good decision-making models and decision-makers must tolerate vagueness or ambiguity and be able to function in unstructured problems (Yu, 2002). Fuzzy Theory is very helpful to deal with the vagueness of human thoughts and language in making decisions (Lin and Wu, 2008). Since the model should work with vague expressions the proposed approach will be based on Fuzzy Set Theory (Zadeh, 1964). The use of fuzzy sets in Human Resources is not a rare thing. Many authors, such as Abdullah and Norsyahida (2015), Mammadova, Jabrayilova and Mammadzada (2016), Kumar and Joshi (2018), Baležentis, Baležentis and Brauers (2012) and Shahhosseini and Sebt (2011), already applied the fuzzy approach on decision making in Human Resources (HR), but approach presented in this article is based on the new way of using α -level cuts created by authors to transform triangular fuzzy number to trapezoidal fuzzy number. This transformation enables taking into account the weight (importance) of a decision-maker within the decision-making group. As it is common, recruitment process includes authorities from different hierarchical level and, thus, with different power of their votes. Therefore, the triangular-trapezoidal transformation creates an opportunity to incorporate different power of votes into the group-decision making process.

For the purposes of this article it is assumed, that candidates are selected by group of employees (decision-makers), where each decision-maker should have a different degree of influence on the final result. Ignoring the relative weights of experts can lead to incorrect and erro-neous results that cannot be compensated in the final solutions (Mianabadi and Afshar, 2008). In this context, the question is how to determine the weight of each member included in the decision-making process. Up to now, many methods have been proposed to determine these weights. However, there is no agreement upon the best method of determining criteria weights, nor there is agreement upon the method of the direct determination of the "real" set of weights. In the literature, however, there is agreement that the weights calculated by a certain method are more accurate than the weights obtained by the methods of a direct weight assignment based on the expert's understanding of the significance of criteria (Pamučar, Stević and Sremac, 2018). For the purposes of this article, the Analytic Hierarchy Process (AHP) has been chosen to establish weights (importance) of members included in the decision-making team.

The aim of this article is to present a coherent approach for selection of candidates that is user-friendly, flexible, precise, working with vague expressions, and applicable in all phases of recruitment.

The paper has been organized as follows: The second chapter describes the used tools and methods with the main focus on fuzzy mathematics and AHP. In the third chapter, the whole approach is described in detail. The fourth chapter provides the case study from the HR environment and in conclusion, the proposed approach and results are evaluated.

2 Materials and methods

Fuzzy Numbers and α-level cuts

The approach is based on the transformation of triangular fuzzy numbers to trapezoidal fuzzy numbers.

A fuzzy set is a generalization of the classical set (crisp set) and the membership function denotes the membership grade of an element to the set. Fuzzy numbers are a special case within fuzzy sets. Thus, a fuzzy set is called fuzzy number if it is convex and normal (Nahmias, 1978).

Triangular Fuzzy Number

A fuzzy number set A is a triangular fuzzy number, if its membership function $\mu_A : \mathbb{R} \to [0,1]$ has the following form

$$\mu_A(x) = \begin{cases} 0 \quad if\ x < a_1 \\ \dfrac{x-a_1}{a_2-a_1} \quad if\ a_1 \le x \le a_2 \\ \dfrac{a_3-x}{a_3-a_2} \quad if\ a_2 \le x \le a_3 \\ 0 \quad if\ x > a_3, \end{cases} \tag{1}$$

where a_1, a_2, a_3 are real numbers and $a_1 \le a_2 \le a_3$. Let us denote a triangular fuzzy number by $A = (a_1, a_2, a_3)$.

The Shape and Position of Triangular Fuzzy Number

The shape of the triangular fuzzy number is one of the important variables that reflect the degree of influence of a member of decision-making group on the final selection. The real number

$$\max\{a_2 - a_1, a_3 - a_2\}$$

will be difference between different vote-levels on the final selection (Figure 1).

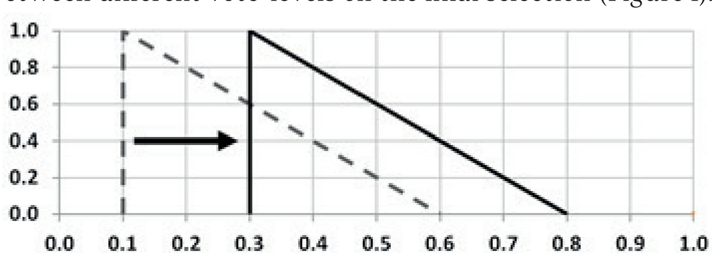

Figure 1: Shape and position of a number

The position of the fuzzy number is crucial to the resulting values. The further the fuzzy number is from the origin, the bigger the resulting value is.

Trapezoidal Fuzzy Numbers

The trapezoidal fuzzy number is determined by four parameters $a_1 \le a_2 \le a_3 \le a_4$ and is characterized by membership function $\mu_A : \mathbb{R} \to [0,1]$ in the form of a trapezoid. For the membership function μ_A applies (Klir and Yuan, 1995):

$$\mu_A(x) = \begin{cases} 0 & if\ x < a_1 \\ \dfrac{x-a_1}{a_2-a_1} & if\ a_1 \le x \le a_2 \\ 1 & if\ a_2 \le x \le a_3 \\ \dfrac{a_4-x}{a_4-a_3} & if\ a_3 \le x \le a_4 \\ 0 & if\ x > a_4, \end{cases} \tag{2}$$

In the following, use the notation $A = (a_1, a_2, a_3, a_4)$ for trapezoidal fuzzy number.

Average of trapezoidal fuzzy numbers

The arithmetic operations with trapezoidal fuzzy numbers are established in the following way. Let $A = (a_1, a_2, a_3, a_4)$ and $B = (b_1, b_2, b_3, b_4)$ be two trapezoidal fuzzy numbers and k a real number. Then, the sum and product is given by

$$A + B = (a_1, a_2, a_3, a_4) + (b_1, b_2, b_3, b_4) = (a_1 + b_1, a_2 + b_2, a_3 + b_3, a_4 + b_4)$$

$$k \times A = (ka_1, ka_2, ka_3, ka_4).$$

The average for n trapezoidal fuzzy numbers $(a_j, b_j, c_j, d_j), j = 1, \ldots, n$ is the following:

$$A_{avg} = \left(\frac{1}{n} \sum_{i=1}^{n} a_i, \frac{1}{n} \sum_{i=1}^{n} b_i, \frac{1}{n} \sum_{i=1}^{n} c_i, \frac{1}{n} \sum_{i=1}^{n} d_i \right). \tag{3}$$

This operation yield trapezoidal fuzzy numbers as a result.

Transformation of Triangular Fuzzy Number to Trapezoidal Fuzzy Number

The following transformation of fuzzy numbers based on α -level cuts is the original ideo of autors.

Suppose, we have a triangular fuzzy number and a real number $\alpha \in [0,1]$ that will arise from influence of a specific member in the decision. The new trapezoidal fuzzy number, which kernel is equal to the α -cut of original triangular fuzzy number, will be called the transformed fuzzy number.

Definition: The transformation of triangular fuzzy number $A = (a_1, a_2, a_3)$ is a trapezoidal fuzzy number $A_\alpha = (a_1, a_{2\alpha}, a_{3\alpha}, a_4)$, where the element a_1 remain the same and elemen a_3 from the original triangular fuzzy number will become element a_4 of the transformed trapezoidal fuzzy number, in other words $a_4 := a_3$. New values of $a_{2\alpha}$ and $a_{3\alpha}$ are calculated using the following formulas:

$$a_{2\alpha} = a_1 + \alpha \times (a_2 - a_1) \tag{4}$$

$$a_{3\alpha} = a_3 + \alpha \times (a_3 - a_2) \tag{5}$$

Then the new fuzzy number will be:

$$A_\alpha = (a_1, a_{2\alpha}, a_{3\alpha}, a_4) = (a_1, a_1 + \alpha \times (a_2 - a_1), a_3 - \alpha \times (a_3 - a_2), a_3). \tag{6}$$

The lower the α is, the greater the influence of a specific member of the decision-making group on the decision will be. Graphical representation of this transformation is shown in the Figure 2.

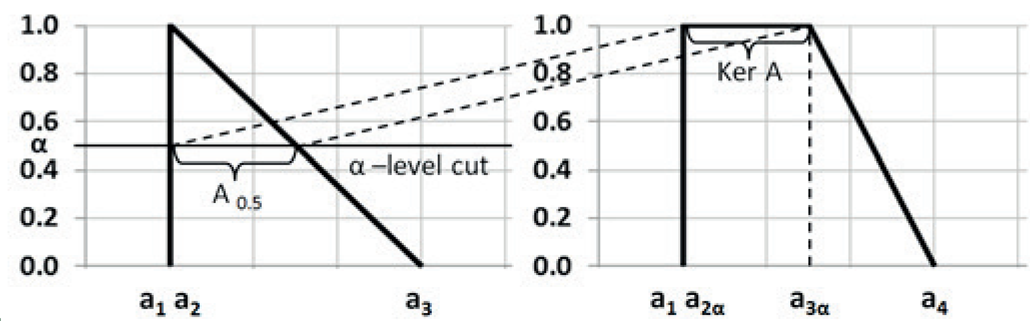

Figure 2: Transformation of trapezoidal fuzzy number

Fuzzy Linguistic Scale

For the purposes of expression of level of agreement, a linguistic fuzzy scale will be used (Table 1). There are many different linguistic scales described for example in Lubiano (2016), Ryjov (2003) or Xu (2012). In this article, the Likert scale will be used. A linguistic variable is defined using a quintuple (X, T, U, G, M) where X is the name of the variable, $T = \{T_1, T_2, \dots, T_n\}$ is the set of terms of X, U is the universe of discourse (generally $[0,1]$), G is a syntactic rule for generating the derived terms, and M is a semantic rule for associating each term with proper fuzzy set (number) defined on U (Zhang, Phillis and Kouikoglou, 2005)

T_j	Linguistic term	Fuzzy number $M\left(T_j\right)=\left(t_{1j},t_{2j},t_{3j},t_{4j}\right)$
T_1	None	(0, 0, 0, 0)
T_2	Very Low	(0.15, 0.15, 0.20, 0.40)
T_3	Low	(0.30, 0.30, 0.35, 0.60)
T_4	High	(0.45, 0.45, 0.50, 0.80)
T_5	Very High	(0.60, 0.60, 0.65, 1)

Table 1: Fuzzy linguistic scale

Hamming distance

The linguistic term expressing the result of candidate selection $A=\left(a_1,a_2,a_3,a_4\right)$ is received using method for determination of distance between numbers. The Hamming distance for trapezoidal fuzzy numbers is defined as follows (Shallit, 2009). Given $A=\left(a_1,a_2,a_3,a_4\right)$ and $B=\left(b_1,b_2,b_3,b_4\right)$ be two trapezoidal fuzzy numbers with membership functions μ_A and μ_B, respectively. The Hamming distance is defined as

$$d_H\left(A,B\right)=\sum_{j=1}^{n}\left|a_j-b_j\right|. \tag{7}$$

The distance coefficient is always between 0 and 1, where 0 refers to the ideal solution.

Analytic Hierarchy Process (AHP)

Analytic Hierarchy Process was developed by Saaty (1977, 1980) and works with both qualitative and quantitative evaluation of preferences. To obtain criteria priorities, pairwise comparisons based on the fundamental verbal/numerical 1-9 scale is required (Saaty, 1987). The number of necessary comparisons for each comparison matrix is $n\left(n-1\right)/2$, where n is the number of elements. Each elements weight is a geometric mean of its comparisons, which are then normalized.

An important requirement is to test consistency of our stated preferences, as human-made decisions can be mutually inconsistent because of the human nature. The most commonly used method for consistency check was developed by Saaty (1977), who proposed a consistency index (CI) related to eigenvalue method. CI is obtained as

$$CI=\frac{\lambda_{\max}-n}{n-1}, \tag{8}$$

where $\lambda_{\max}$ is the maximal eigenvalue of the pairwise comparison matrix. The consistency ratio (*CR*) is given by

$$CR = \frac{CI}{RI}, \quad (9)$$

where *CR* is the random index obtained in Table 2.

n	3	4	5	6	7	8	9	10
RI	.58	.9	1.12	1.24	1.32	1.41	1.45	1.49

Table 2: AHP - Random indices (Saaty, 1977)

The priorities are considered consistent if the consistency ration is less than 10%. Super Decisions software is used to count the criteria preferences and to test consistency of the preferences.

Process of the Decision-making

In this section, each step for the selection of suitable candidates by group of decision-makers is described.

Step 1: Determination of Criteria

The first step of this approach is the determination of criteria by which the weight of a member in the decision-making group will be set. Saaty (2006) is proposing criteria such as expertise, experience, previous performance, effort on the problem, etc. to determine the weight of the decision-maker in a group. For purposes of the case study the decision-makers position in the hierarchy of an organization will be used as the criteria to set weights. More precisely, in the case of this article, we use four different hierarchical levels: Head of faculty, Head of research department, Head of study program and Researchers.

Step 2: Determination of weight of each member of the decision-making group

To determine the weights (importance) of each hierarchical level, we applied the AHP method and expert evaluation. Based on the estimation of authors, the Head of faculty is twice more important than Head of research department, three-times more important than Head of study program and, finally, four-times more important than researchers. The importance of the other pairwise comparisons considers same distances as in the case of the first description. Thus, the importance of the Head of faculty level is 46.730%, Head of research department 27.718%, Head of study program 16.009% and 9.543% to Research level. The inconsistency of the evaluation was 1.16%.

Step 3: Selection of Fuzzy Linguistic Scales

In this step, it is necessary to define the linguistic scales and related fuzzy numbers. To ex-press the level of agreement with the possible result, Likert balanced scale on universum $\langle 0,1 \rangle$ is be used. The greater the number of scale categories is, the more accurate the resulting evalu-ation will be. As a compromise the five-part scale (Strongly agree – Agree – Undecided – Dis-agree – Strongly agree) is used considering question: Would you like to contract following candidate for the research position.

Such scales are easy to construct and administer and are easy for the respondent to understand (Chen, 2017). The fuzzy linguistic scale described in Table 3 and Figure 3 will be used in the case study to express the level of agreement with the ac-ceptance or not of a candidate.

Linguistic term	Fuzzy number
Strongly Agree	(0.75, 0.75, 0.75, 1.00)
Agree	(0.65, 0.65, 0.65, 0.90)
Undecided	(0.45, 0.50, 0.50, 0.55)
Disagree	(0.10, 0.35, 0.35, 0.35)
Strongly Disagree	(0.00, 0.25, 0.25, 0.25)

Table 3: Five-point scale

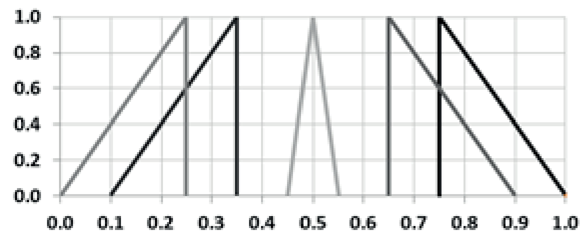

Figure 3: Five-point scale

Finally, the fuzzy linguistic scale described in Table 4 and Figure 4 will be used in the case study for interpretation of the overall result.

Linguistic term	Fuzzy number
Accept the candidate	(0.75, 0.75, 0.80, 1.00)
Renegotiate (next round)	(0.45, 0.49, 0.50, 0.55)
Reject the candidate	(0.00, 0.20, 0.25, 0.25)

Table 4: Three-point scale

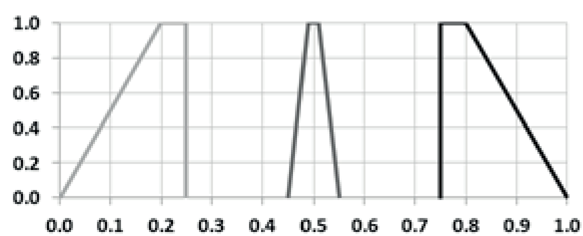

Figure 4: Three-point scale

All proposed scales were created base on the estimation of authors.

Step 4: Voting of individual members of the decision-making group

In this step, each member of the decision-making group votes on the prearranged fuzzy linguistic scale to express the level of consent. If the decision maker's weight is $\alpha < 1$ then the transformation of the fuzzy number through the chosen α -level should be done. Based on Formula (3) the average fuzzy number resulting from votes of all members of decision-making group should be done. Based on the Hamming distance approach, the difference between the resulting average number and possible results described on the fuzzy linguistic scale is calculated. The possible resulting variant described on the fuzzy linguistic scale which is closest to the calculated average fuzzy number should be considered as the final result of the voting.

III RESULTS

In this case study, a Human Resources example from a university environment is presented. The goal of the case study is to decide on a suitability of a candidate for a particular research position described in Table 5.

Name of the vacancy:	Full Time Research Professor (Administration)
Field:	Social Sciences
Discipline:	Management of Risks
Specialization:	Management of operational risks in companies
Required academic degree:	Doctoral degree or higher
Responsibilities:	Development of research projects, generation of knowledge products, management of undergraduate and postgraduate theses, teaching management, organization of student meetings and research competitions.
Required skills and languages:	Research: Coordination of projects in collaboration with other researchers, professors and students Experience in laboratory and field.
Skills:	Teamwork, leadership, resilience, assertive communication, commitment and dedication.
Languages:	Management of Spanish and English.
Necessary experience:	Training in Management or Operational Engineering with guidance in the area of operational risks, monitoring and control of risks in companies. In research: Experience in scientific production published in indexed journals, chapters in books and books in the last 3 years in the area of risk analysis, which belongs to the SIN National System of Researchers (or at least with the SIN profile). Experience teaching undergraduate and postgraduate students.

Table 5: Description of research vacancy

Reduced description of candidate's education, skills and interests is shown in Table 6.

Age:	29 years old.
Education:	Last year of doctoral study.
Employment History:	8 years of work experience in risk and project management.
Additional Training:	• PRINCE2 Foundation Certificate in Project Management • Business Continuity Manager • Visual Basic for Application – advanced •Crisis PR Company Communication
Research Interests:	• Decision-making models and Multi-Criterial Decision Analysis (MCDA) with focus on Fuzzy Set Theory. • Crisis management and methods of Crisis Management in education. • Project management and methods of Project Management in education. • Mathematical methods in economics (Linear Programming, Simulation Methods, Stochastic Models, Transportation Models).
Publications:	Four contributions at international conferences with focus on management.
Grants:	Leader of one grants with approx. value 4, 500 EUR and member participant in a grant with approx. value 5, 000 EUR.

Table 6: Reduced description of the candidate

A nine-member decision-making group was set up in order to decide whether this candidate is suitable for the research vacancy. This group is consisting of people who are at different levels in the university hierarchy. The group includes five researchers, one Head of the study program related to the described vacancy, one Head of the research department and, finally, two Heads of the faculty (representatives of managerial positions). Weights represented by α were assigned to individual members, depending on their position in the hierarchy, as in the chapter Process of the Decision-making is shown. The lower the α is the bigger the impact of the member on final result should be. Therefore, the obtained weights were inverted and normalized to assign one to the lowest level in the hierarchy (researcher). The assigned weights are presented in Table 7.

Member	Position in the Hierarchy	Weight (α)
Member 1	Head of the faculty	0.10
Member 2	Head of the faculty	0.10
Member 3	Head of the research department	0.21
Member 4	Head of the study program	0.46
Member 5	Researcher	1
Member 6	Researcher	1
Member 7	Researcher	1
Member 8	Researcher	1
Member 9	Researcher	1

Table 7: Members of the decision-making group with assigned weights

Based on the information received about the candidate, each member of the decision-making group voted with respect to the stated question: Would you like to contract following candidate for the research position? The votes and corresponding fuzzy numbers based on the Table 3 are presented in Table 8.

Member	α	Vote	Triangular Fuzzy Number
Member 1	0.10	Agree	(0.65, 0.65, 0.65, 0.90)
Member 2	0.10	Agree	(0.65, 0.65, 0.65, 0.90)
Member 3	0.21	Undecided	(0.45, 0.50, 0.50, 0.55)
Member 4	0.46	Undecided	(0.45, 0.50, 0.50, 0.55)
Member 5	1	Disagree	(0.10, 0.35, 0.35, 0.35)
Member 6	1	Agree	(0.65, 0.65, 0.65, 0.90)
Member 7	1	Agree	(0.65, 0.65, 0.65, 0.90)
Member 8	1	Agree	(0.65, 0.65, 0.65, 0.90)
Member 9	1	Undecided	(0.45, 0.50, 0.50, 0.55)

Table 8: Votes of members and corresponding fuzzy numbers

The α assigned to each member as the weight of the member will be used to transform the original triangular fuzzy number to transformed fuzzy number as described before. The process of the transformation can be seen in Table 9. The transformed numbers and the average fuzzy number arising from the transformed numbers are based on Formula (3). As one can see, the Researches remain with the same fuzzy number, since their α is equal to 1. But the rest of triangular fuzzy numbers has changed in order to reflect the different weight regarding the hierarchical structure.

The results are divided into two basic parts. First, results related to course popularity are presented and discussed considering general and gender point of view. In addition, obtained differences between these models are discussed as well. Second, the relation between training programs popularity and their effectiveness in employees' performance improvement are analyzed. Similarly, gender perspective is taken into consideration.

Triangular Fuzzy Number	Transformed number
(0.65, 0.65, 0.65, 0.90)	(0.65, 0.65, 0.87, 0.90)
(0.65, 0.65, 0.65, 0.90)	(0.65, 0.65, 0.88, 0.90)
(0.45, 0.50, 0.50, 0.55)	(0.45, 0.46, 0.54, 0.55)
(0.45, 0.50, 0.50, 0.55)	(0.45, 0.47, 0.53, 0.55)
(0.10, 0.35, 0.35, 0.35)	(0.10, 0.35, 0.35, 0.35)
(0.65, 0.65, 0.65, 0.90)	(0.65, 0.65, 0.65, 0.90)
(0.65, 0.65, 0.65, 0.90)	(0.65, 0.65, 0.65, 0.90)
(0.65, 0.65, 0.65, 0.90)	(0.65, 0.65, 0.65, 0.90)
(0.45, 0.50, 0.50, 0.55)	(0.45, 0.50, 0.50, 0.55)
Avg.	(0.52, 0.56, 0.62, 0.72)

Table 9: Transformation of fuzzy numbers

Based on the Hamming distance of the calculated average fuzzy number and possible results presented on fuzzy linguistic scale described in Table 4 the output of this voting should be "Renegotiate (next round)". This means that new discussions should be launched, candidate should be invited to a next round and/or asked for additional information). The calculated Hamming distances are presented in the Table 10 below.

Variant of the result	Hamming distance
Accept the candidate	0.871
Renegotiate (next round)	0.428
Reject the candidate	1.727

Table 10: Hamming distance for each result of the recruiting process

IV DISCUSSION

Level of Democracy

Group decision-making usually incorporates members of different hierarchical levels. It is not common that all members have the same power of his/her vote. Therefore, it is important to be able to express different importance of each member. The presented fuzzy group decision-making models enable this due to the α levels. More precisely, as the importance levels are calculated by AHP method, the stated preferences in Step 2 can be modified. For example, to express higher importance of the managing position, the importance can be modified as the Head of faculty is three-times more important than Head of research department, five-times more important than Head of study program and, finally, seven-times more important than researchers. This modification will lead to strengthen voting power of the managing position resulting in importance of the Head of faculty level is 56.501% (+9.771% compare to the original model), Head of research department 26.220% (-1.498%), Head of study program 11.750% (-4.259%) and 5.529% (-4.014%) for Researchers. This process can be modified in many ways regarding the fundamental verbal/numerical 1-9 Saaty scale (Saaty, 1987) operating between fully democratic decision-making (not applicable for the α cuts due to indifferent changes of fuzzy numbers) and fully dictatorial environment (also not applicable on our case).

Accuracy of Results

It is well known that accuracy of results is an important component of most models. Capturing of subjectivity, uncertainty and ambiguity of decision-makers are secured by fuzzy linguistic scales. As Ertugrul Karsak (2001) confirms, fuzzy set theory appears to be suitable tool for this. The possible weekness regarding accurancy can be found in correct setting of the fuzzy linguistic scales, more precisely in the setting of slope and position of fuzzy numbers. The slope and position of the fuzzy numbers should be set by an expert or group of experts who determine what values a specific fuzzy number can reach. This would enable us to eliminate (or diminish) the subjectivity in the decision-making process. Furthermore, the accuracy of the entire approach is supported by the fact that there is no defuzzification used during whole decision-making process. The whole approach starts and ends with fuzzy interpretation. Also, it should be noted that classic linear fuzzy numbers do not always have to be sufficient. It would probably be necessary to use non-linear or curved fuzzy numbers for more complex and accurate evaluations in some cases.

Applicability of the Proposed Approach

Decision-making in a group of people with a hierarchical structure is nothing rare and can be found in many different environments of our society, starting with formal organizations as big companies and ending with less structured environments as families. The presented approach is dealing with this kind of decision-making problems, could be widely applicable and offer an interesting alternative to the procedures that Safarzadeh, Khansefid and Rasti-Barkozi (2018), Ren, Xu and Liao (2016), Cho et al. (2019) and many others are suggesting.

V CONCLUSION

Decision-making usually includes ambiguity in the decision environment, as well as in decision-maker's expressions. People usually do not work with exact information. In this case, fuzzy decision-making models help us to manage this imprecise ambiguous information. As the case study indicates, the proposed approach provides accurate outputs (results) while working with vague concepts. The approach with transformation of fuzzy numbers could be also used in many areas where it is necessary to take into account weights, not only in a group decision-making. The possible examples can be weights of individual regions or weight in competency models as for example outlined by Brožová et al. (2009).

As mentioned in Discussion, in the context of further research, it would be useful to focus on more precise slope adjustment of fuzzy linguistic scales and consider a possibility of using non-linear fuzzy numbers as well.

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