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Rasim Alguliyev, Ramiz Aliguliyev & Farhad Yusifov

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METHODOLOGIES AND APPLICATION

Modified fuzzy TOPSIS + TFNs ranking model for candidate selection using the qualifying criteria

Rasim Alguliyev[1] · Ramiz Aliguliyev[1] · Farhad Yusifov[1]

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Abstract
Currently, globalization process significantly impacts not only technological, economical, but also social, political and cultural fields. Ongoing social, economic and political processes demonstrate their impacts, and countries are governed by different regimes and government forms. From this standpoint, there is a need for qualified, competent staff for operation of the regimes and governments. In the article researches, which criteria or factors must be taken into account for selection of competent candidates that are suitable for relevant positions during the election process in contrast to traditional voting. Criteria for candidates' selection include adoption of democratic principles, age, education, government agency experience, professional competence, global culture and value acknowledgement, influence in voting area, leadership skills, activity in social media, etc. In the article implemented multi-criteria evaluation approach for candidate selection. Candidates are ranked based on criteria selected using modified fuzzy TOPSIS and triangular fuzzy numbers ranking methods and different aggregation operators. Candidates are ranked by applying both methods in a numeral experiment, and obtained results are compared. Proposed fuzzy multi-criteria decision-making model allows determining a compromise solution in candidate selection.

Keywords Election systems · Voting · Candidate selection · Fuzzy MCDM · Ranking triangular fuzzy numbers · Positional ranking

1 Introduction

Currently, development of e-government is considered a priority direction for all countries. E-government solutions' processing and formation of e-democracy mechanisms significantly impact public administration and political processes (Musial-Karg 2014; Alguliyev and Yusifov 2016b, 2016c). Transformation of citizen rights, implementing citizen participation in social-political processes and decision making is directed toward development of e-participation mechanisms. From this point of view, e-voting is analyzed as one of the mechanisms intended for development of e-participation. (Kumar 2011; Musial-Karg 2014; Awad and Leiss 2016; Wang et al. 2017). Election process distinguishes one country from another not only based on election method of candidates (for example, majority or proportional method), but also procedures, methods and organizational issues applied during voting. Regardless of voting method (traditional, e-voting, online voting, etc.), selection and evaluation of candidates is an important issue and directly affects voting results (Bormann and Golder 2013; Grofman 2016; Gibson et al. 2016; Vassil et al. 2016; Awad and Leiss 2016).

People face different choices throughout their lives and must make decisions. They make a selection among different alternatives in order to meet personal or social demands. It is quite difficult to select the most relevant alternative (Kazana et al. 2015). Selection criteria are one of the difficulties of the decision-making process. Selection criterion is determined as "criterion to achieve a goal." So, decision-making criterion plays an important role in making a selection among alternatives. Usually, difficulty is not experienced when decision is made based on one criterion. However, in this case, alternatives are compared based on one criterion and it is easy to select a relevant alternative.

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✉ Farhad Yusifov
farhadyusifov@gmail.com

[1] Institute of Information Technology, Azerbaijan National Academy of Sciences, Baku, Azerbaijan

As an example, we can point out election of candidates based on social influence in traditional elections. Lack of multiple criteria does not create any difficulties in candidates' election and people participate in elections vote for candidates based on knowledge or intuition.

This example can be applied to internet voting or e-voting carried out in many countries (Gibson et al. 2016; Awad and Leiss 2016; Wang et al. 2017).

In all situations, people make selections and decisions. From this prism, multi-criteria decision-making concept was determined as decision making in the context of existence of multiple criteria and completely opposite criteria. (Zionts 1979; Kazana et al. 2015). Multi-criteria decision-making (MCDM) methods allow the decision maker to make rapid and correct decisions by conducting multi-criteria evaluation. Currently, MCDM methods are applied in nearly all fields of science. The literature contains a lot of MCDM methods in many fields such as selection of suitable employees during recruitment, selection of equipment in manufacturing field, selection of projects, etc.; however, there are few studies and approaches regarding its application in selection of relevant candidate in election process (Royes and Bastos 2001a, b; Gungor et al. 2009; Dursun and Karsak 2010; Kabak et al. 2012; Kazana et al. 2015; Tuan 2017). This can be related to complexity of political processes, difficulty to choose criteria, protection of human rights and relevance from democratic values' standpoint.

Elections form the basis of democratic governance system. Elections are considered as the main tool to ensure sensitivity and responsibility of the government toward the citizens. Moreover, this depends on the rules applied during elections (Powell 2000; Bormann and Golder 2013). Election process includes conduction of elections, determination of election results and all legal norms that regulate the rules and election relations regarding exercise of election rights (Menocal 2011; Shahandashti 2016).

While analyzing international experience, it becomes clear that electoral systems can be different. The main reason for that is discrepancy between criteria selected for evaluation of each electoral system. Each country selects a system that is considered democratic, suitable and allows economic progress, continuous development and stability. Multitude of electoral systems is related to incomplete contentment of all political powers with these systems, existence of advantages and disadvantages of one system over another. From this standpoint, political authority and legislative power of the country adapt an electoral system that they consider more relevant. Two main forms of electoral systems are distinguished in international experience—plurality–majority and proportional representation (Bormann and Golder 2013; Menocal 2011; Grofman 2016). However, some countries use both systems especially during parliament elections, which are called mixed or semi-proportional system (Moser and Scheiner 2004; Menocal 2011).

The objective of the research is to evaluate qualified, competent candidates based on criteria during election process and make correct decision during election.

2 Contemporary electoral systems and candidate selection criteria

Elections are indicators of political development and role of the people in government. Voting system or electoral systems as a tool allow voters to make a decision during elections or political referendums among alternatives. Officially, study of determined electoral system is called election theory or voting theory, as well as being a subfield of political science, economy and computer science. (Shahandashti 2016; Farmani and Jafari 2016). Application of election rules and people's participation in elections reflects the relations between the government and people, and so to speak creates "social constitution." From this standpoint, selection of an electoral system is one of the important institutional decisions for any democratic state.

Several electoral systems are used worldwide, and some countries even use different electoral systems for local and regional levels (for example, city mayor's office, government agencies, governorship, etc.) (Moser and Scheiner 2004; Menocal 2011; Bormann and Golder 2013; Shahandashti 2016; Farmani and Jafari 2016). In many cases, selection of a particular electoral system can have the power to significantly impact the future political life of the country (Grofman 2016; Farmani and Jafari 2016). From the standpoint of appointing candidates for the positions of government significance, elections allow to use different methods to elect candidates. Here, criteria for candidate selection are one of the subtlest moments. Many countries, as well as European Union countries, conduct party candidate selection procedure generally based on four indicators (Pilet et al. 2015; Meserve et al. 2017):

1. Special rules for individual candidacy on individual level (including remit rules);
2. Special rules regarding party-level candidacy (including gender and minority regulations);
3. Determination of selectorate in candidate selection procedure;
4. Determination of area, region level in candidate selection procedure.

Requirements for putting forth the candidacy of national political parties include the requirement for any form of approval of candidacy, requirements of party membership, age limit, inconsistency requirement, etc.

Special rules regarding party-level candidacies include gender, ethnic, geographical, linguistic quote or balance, quote for citizen society candidates, etc.

Selectorate is determined in accordance with existing requirement and party regulations. Party leader, parliament party, all party members, etc. can be selectorate, based on requirements.

Requirements on determination of area and region levels in candidate selection procedures include organization of election constituencies, regional, national organizations, other political actors, European parties, etc.

Besides, in practice, candidacy, individual and collective criteria are unofficially used together with official regulations for European elections (Pilet et al. 2015).

In general, we must note that multiple criteria at decision-making stage during candidate selection bring the MCDM methods up to date. As seen from literature analysis, there is no standardized systematicity at government-level elections or determination of deputy candidacies from political parties (Pennings and Hazan 2001; Siavelis and Morgenstern 2008; Kazana et al. 2015). As parties place more emphasis on qualification, researches consider several official or unofficial criteria. It is presumed that mainly the following criteria (as shown in Table 1) are taken into account in candidate selection (Pilet et al. 2015; Kazana et al. 2015):

3 Related works

Candidate selection is a process where the best candidate is selected in order to take a certain vacant position. Different methods and technologies that help the decision makers to presume the level of future success of the candidate at the workplace are applied during the process of recruitment, taking the certain vacant position and selection. (Tuan 2017; Afshari et al. 2017; Borissova 2018).

Staff recruitment and selection process always start with preliminary determination of characteristics of the job, i.e., job analysis is performed, and then recruitment, selection and evaluation process of the candidates that meet the requirements is carried out (Gungor et al. 2009; Dursun and Karsak 2010; Kabak et al. 2012; Karabasevic et al. 2015). Literature analysis demonstrates that different areas apply MCDM methods (Khorami and Ehsani 2015; Tuan 2017; Afshari et al. 2017; Borissova 2018). MCDM models have been applied in solution of different complicated decision-making problems. AHP, PROMETHEE, ELECTRE, SAW, ARAS, COPRAS, MOORA, MULTIMOORA, WASPAS CP, VIKOR, TOPSIS and many other methods have been developed for decision-making problems' solution (Karabasevica et al. 2015; Alguliyev et al. 2016; Khorami and Ehsani 2015; Mardani et al. 2015; Khorami and Ehsani 2015). Many studies were dedicated to MCDM methods' comparison and overview (Turskis and Zavadskas 2011; Stanujkic et al. 2013; Zavadskas et al. 2014; Mardani et al. 2015; Khorami and Ehsani 2015).

Literature analysis demonstrates that many research works are dedicated to fuzzy MCDM methods' application. Fuzzy MCDM methods are widely used for ranking of alternatives characterized with fuzzy numbers based on many criteria.

Capaldo and Zollo (2001) focused on rating scale for staff assessment, and authors attempted to increase the effectiveness of staff assessment of the company operating in scientific research field. Management skills, staff characteristics and competence were proposed as three main criteria groups. Dursun and Karsak (2010) proposed a fuzzy MCDM method for staff selection. Ordered weighted averaging (OWA) operator was used to aggregate information. Selection of staff based on proposed model was reviewed, and empirical evaluation was performed based on developed model. Kelemenis and Askounis (2010) focused on supporting decision-making process for selection of information technologies. Research develops a fuzzy TOPSIS method based on veto concept. Fuzzy linguistic variables are used to evaluate the importance of criteria and suitability of candidates to the criteria, and empirical calculation is carried out based on proposed model. Rouyendegh and Erkan (2013) study proposed fuzzy ELECTRE algorithm to select the best candidate and academic staff based on expert feedback in group decision-making environment. Authors propose a hierarchic

Table 1 Deputy candidates' evaluation criteria

Personal or character traits	Social relations
Adoption of democratic principles	Adoption of national culture and values
Age	Familiarity with global culture
Marital status	Prosecution
Health status	Recognition of the election area
Education level	Recognition of the election area
Government agency experience	Presentation and representation skills
Professional competence	Evaluation of party leaders
Participation in local and international projects	Activity in social media (followers)

diagram to select staff and classify three main criteria for decision making as academic, work and individual factors. Proposed method allows expressing all pair comparisons with triangular fuzzy numbers (TFNs) in order to achieve consensus among decision makers. Tuan (2017) study develops an extended fuzzy MCDM method to evaluate staff and support the selection process. Proposed MCDM method evaluates the rank of different alternatives in comparison with selective criteria, and weights of all criteria using linguistic terms generally expressed in fuzzy numbers. Fuzzy MCDM proposed in the study is applied for solution of selection and evaluation issues of lecturer. Alguliyev et al. (2016) proposed a hybrid fuzzy MCDM for staff evaluation. Proposed hybrid method is based on unification of fuzzy TOPSIS method with fuzzy worst-case (entropy) method for linguistic judgement. Authors formed an expert group consisting of decision makers in order to evaluate the alternatives. Experimental evaluation was performed, and application possibilities of the proposed method were demonstrated. Borissova (2018) studies the group decision-making problem when experts have different experiences and competences. A group decision-making model is proposed by assigning weight coefficients to experts with different competencies. Obtained results demonstrate the application and efficiency of the model in staff selection.

Literature analysis contains studies on application of MCDM methods for candidate selection during election process. Royes and Bastos (2001a) is dedicated to use of fuzzy MCDM method in election prediction. As a practical result of the study, a computational system is proposed for election forecasting. Proposed flexible system allows selecting fuzzy weights or fuzzy evaluation functions of the criteria based on decision maker's (system user) requirements. Kazana et al. (2015) in research determined common 15 basic criteria taking into consideration while political parties elect deputy candidates in general. Weights of the criteria are evaluated by the party members using AHP method by application of FARE (Factor Relationship) method. Candidates are evaluated based on criteria selected by application of MCDM method. Study performs an empiric evaluation and ranks deputy candidates by application of MCDM method.

4 Fuzzy TOPSIS + ranking TFNs methods for candidate selection

Voting is a fundamental decision-making tool in any consensus-based society. Citizens' participation in political processes and allowing to vote during important decision making, provision of direct participation, forms the basis of democracy. From this point of view, considering the democratic processes, development of effective solutions of e-voting is a topical issue.

This study proposes methods for selection of candidates in election process based on fuzzy TOPSIS (technique for order of preference by similarity to ideal solution) and triangular fuzzy numbers (TFNs) ranking method. TOPSIS method allows calculating the integral index for alternatives considering multiple criteria, thus providing the ranking of alternatives for option selection procedure with participation of the decision maker. Fuzzy TOPSIS method was used for selection, ranking of alternatives and making group decisions in many applied issues (Capaldo and Zollo 2001; Dursun and Karsak 2010; Kelemenis and Askounis 2010; Chang, Yeh and Chang 2013; Rouyendegh and Erkan 2013; Alguliyev et al. 2016; Tuan 2017). Let's note that AHP (analytical hierarchy process) method most often used to multi-criteria ranking of alternatives has several disadvantages. This includes high calculation load, contradiction of expert evaluations when the number of experts is high, etc. (Alguliyev et al. 2016).

The objective of the study is selection of a suitable, qualified candidate unlike traditional voting for candidate elections. Proposed approach is based on multi-criteria evaluated of candidates selected as a result of voting based on determined criteria. Selection criteria of candidates include acceptance of democratic principles, age, education, government agency experience, professional proficiency, global culture proximity and values, prestige in election area, leadership skills, activity in social media and other. Each voter evaluates the candidate based on selected criteria and performs multi-criteria selection. Problem is stated as follows.

Let's review candidate selection issue based on fuzzy TOPSIS method.

Let's assume that n number of A_i, $i = 1, 2, \ldots, n$, candidate sets must be evaluated by K number of decision-maker group (voters), V_k $(k = 1, 2, \ldots, K)$ based on m number of C_j, $j = 1, 2, \ldots, m$, criteria. Criteria are not co-dependent, have equal significance and can be evaluated.

Evaluation is performed by each V_k decision maker in order to define $S^k = \left\| s_{ij}^k \right\|$, $i = 1, 2, \ldots, n$; $j = 1, 2, \ldots, m$; $k = 1, 2, \ldots, K$ decision matrix.

Fuzzy TOPSIS method consists of the following stages (Chang et al. 2013; Alguliyev et al. 2016).

Step 1. *Construct a decision matrix.* S^k decision-making matrix is developed as follows: $S^k = \left\| s_{ij}^k \right\|$, where s_{ij}^k is the evaluation of i-th A_i alternatives in relation to j-th C_j criterion by V th V_k decision maker.

Step 2: *Criteria and selection of linguistic variables for alternatives with respect to criteria.* Decision maker prefers to express his opinion using linguistic variables due to uncertainty. Linguistic variable is a variable with linguistic term value. Each linguistic value can be described using a fuzzy number to which a membership function can be assigned. There are different forms of fuzzy numbers, including TFNs, which is more popular. This is a fuzzy number described using three dots as follows: $s_{ij}^k = \left(l_{ij}^k, m_{ij}^k, u_{ij}^k\right)$, where m_{ij}^k is the most possible value of the variable, l_{ij}^k and u_{ij}^k are correspondingly high and low values to describe the fuzziness of evaluation, $l_{ij}^k \le m_{ij}^k \le u_{ij}^k$. As a membership function, this expression can be explained as follows:

$$\mu_{s_{ij}^k}(s) = \begin{cases} 0, & s < l_{ij}^k \\ \dfrac{s - l_{ij}^k}{m_{ij}^k - l_{ij}^k}, & l_{ij}^k \le s \le m_{ij}^k \\ \dfrac{u_{ij}^k - s}{u_{ij}^k - m_{ij}^k}, & m_{ij}^k \le s \le u_{ij}^k \\ 0, & s > u_{ij}^k \end{cases}$$

Step 3: *Calculation of aggregate fuzzy rating for alternatives*. If the fuzzy rating of all decision makers can be determined as $s_{ij}^k = \left(l_{ij}^k, m_{ij}^k, u_{ij}^k\right)$ like TFNs and decision makers are equally important, then aggregate fuzzy decision matrix $\tilde{S} = [\tilde{s}_{ij}]$, $\tilde{s}_{ij} = \left(\tilde{l}_{ij}, \tilde{m}_{ij}, \tilde{u}_{ij}\right)$, can be defined as follows using arithmetic mean operator (Chang et al. 2013):

$$\tilde{l}_{ij} = \frac{1}{K}\sum_{k=1}^{K} l_{ij}^k, \quad \tilde{m} = \frac{1}{K}\sum_{k=1}^{K} m_{ij}^k, \quad \tilde{u} = \frac{1}{K}\sum_{k=1}^{K} u_{ij}^k, \quad i = 1,2,\ldots,n; \quad j = 1,2,\ldots,m$$

Step 4: *Normalize the aggregate fuzzy decision matrix.* We determine the normalized aggregate fuzzy decision matrix marked with $Y = [y_{ij}]$ as follows:

$$y_{ij} = (l_{ij}, m_{ij}, u_{ij}) = \left(\frac{\tilde{l}_{ij}}{\tilde{u}_j^+}, \frac{\tilde{m}_{ij}}{\tilde{u}_j^+}, \frac{\tilde{u}_{ij}}{\tilde{u}_j^+}\right)$$
$$\text{and } \tilde{u}_j^+ = \max_{i=1,2,\ldots,n} \{\tilde{u}_{ij}\} \quad \text{(for benefit criteria)}$$

$$y_{ij} = (l_{ij}, m_{ij}, u_{ij}) = \left(\frac{\tilde{l}_j^-}{\tilde{u}_{ij}}, \frac{\tilde{l}_j^-}{\tilde{m}_{ij}}, \frac{\tilde{l}_j^-}{\tilde{l}_{ij}}\right)$$
$$\text{and } \tilde{l}_j^- = \max_{i=1,2,\ldots,n} \{\tilde{l}_{ij}\} \quad \text{(for cost criteria)}$$

Step 5: *Construct the normalized fuzzy decision matrix.* Normalized fuzzy decision matrix $Y = [y_{ij}]$, $i = 1,2,\ldots,n; j = 1,2,\ldots,m$, is made.

It must be noted that y_{ij} is a TFN described by $y_{ij} = (l_{ij}, m_{ij}, u_{ij})$.

Step 6: *Determining fuzzy positive ideal solution and fuzzy negative ideal solution.* A^+ fuzzy positive ideal solution and A^- fuzzy negative ideal solution can be determined as follows based on normalized values:

$$A^+ = (a_1^+, a_2^+, \ldots, a_m^+) \text{ here } a_j^+ = (u_j^+, u_j^+, u_j^+) \text{ and } u_j^+ = \max_{i=1,2,\ldots,n} \{u_{ij}\}$$

$$A^- = (a_1^-, a_2^-, \ldots, a_m^-) \text{ here } a_j^- = (l_j^-, l_j^-, l_j^-) \text{ and } l_j^- = \min_{i=1,2,\ldots,n} \{l_{ij}\}$$

Step 7: *Calculation of distance from each alternative to fuzzy positive ideal solution and fuzzy negative ideal solution.* $A^+ = (a_1^+, a_2^+, \ldots, a_m^+)$ distance from each $A_i = (y_{i1}, y_{i2}, \ldots, y_{im})$ alternative to fuzzy positive ideal solution can be calculated by measuring the distance between two fuzzy numbers based on Euclidean distance:

$$D_i^+ = \sqrt{\sum_{j=1}^{m} \left(dist(y_{ij}, a_j^+)\right)^2}$$

In the same way, distance from each $A_i = (y_{i1}, y_{i2}, \ldots, y_{im})$ alternative to $A^- = (a_1^-, a_2^-, \ldots, a_m^-)$ fuzzy negative ideal solution can be calculated as distance as follows:

$$D_i^- = \sqrt{\sum_{j=1}^{m} \left(dist(y_{ij}, a_j^-)\right)^2}$$

Distance $dist(y_{ij}, a_j^+)$ between two TFNs $y_{ij} = (l_{ij}, m_{ij}, u_{ij})$ and $a_j^+ = (u_j^+, u_j^+, u_j^+)$, as well as distance $dist(y_{ij}, a_j^-)$ between two TFNs $y_{ij} = (l_{ij}, m_{ij}, u_{ij})$ and $a_j^- = (l_j^-, l_j^-, l_j^-)$ correspondingly, is calculated as follows:

$$dist(y_{ij}, a_j^+) = \sqrt{\frac{1}{3}\left[(l_{ij} - u_j^+)^2 + (m_{ij} - u_j^+)^2 + (u_{ij} - u_j^+)^2\right]}$$
$$dist(y_{ij}, a_j^-) = \sqrt{\frac{1}{3}\left[(l_{ij} - l_j^-)^2 + (m_{ij} - l_j^-)^2 + (u_{ij} - l_j^-)^2\right]}$$

Step 8: *Calculation of CI_i (closeness) index of each alternative*. CI_i closeness index shows the distance to fuzzy positive ideal solution A^+, as well as fuzzy negative ideal solution A^-. Closeness index CI_i *of each* A_i alternative is calculated as follows:

$$CI_i = \frac{D_i^-}{D_i^- + D_i^+}, \quad i = 1,2,\ldots,n$$

Due to $D_i^+ \ge 0$ and $D_i^- \ge 0$, it is clear that CI_i value is in interval between 0 and 1. Higher the CI_i *index values, more productive are* the alternatives.

Step 9: *Ranking the alternatives.* A_i alternatives are ranking in descending order based on CI_i values, and alternatives with the highest CI_i values are selected.

Ranking of triangular fuzzy numbers Together with fuzzy TOPSIS method, TFNs ranking method based on aggregate fuzzy rating of the candidates is used to select candidates in accordance with Step 3 and results obtained through both methods are compared. Fuzzy number ranking and comparison has a practical significance in practice. Fuzzy number ranking is widely applied in forecasting, optimization, social-economic sciences, uncertain environment management, risk analysis, fuzzy systems and especially decision-making problems (Akyar et al. 2012; Boulmakoul et al. 2013; Hajjari 2015; Nguyen 2017). Different methods were developed for ranking of fuzzy numbers, but majority caused broad discussions due to calculation complexity and different deficiencies. In article uses TFNs ranking method proposed by Akyar et al. (2012), based on their incenter and inradius, to rank the candidates. Based on the method proposed by Akyar et al. (2012), let's assume that we are given a triangle with three vertices coordinates (x_A, y_A), $(x_B, y_B)\,(x_C, y_C)$ and the opposite sides of the triangle have lengths a, b, c, respectively (as shown in Fig. 1).

Based on known Heron's formula, the area of triangle ΔABC is equal to the product of r inradius of triangle (incircle) and s semiperimeter of the sides:

$$|\Delta ABC| = rs, \quad r = \frac{\sqrt{s(s-a)(s-b)(s-c)}}{s}, \quad s = \frac{a+b+c}{2}$$

Incenter of the triangle (incenter) is calculated using the following formula (Akyar et al. 2012):

$$I_{center} = \frac{a(x_A, y_A) + b(x_B, y_B) + c(x_C, yC)}{P} \tag{1}$$

where P is the perimeter of ΔABC triangle.

Here, let's review ranking of triangular fuzzy numbers proposed by Akyar et al. (2012). Let's assume that $\tilde{A} = (l, m, u)$ TFNs are given. $(x_A, y_A) = (m, 1)$, $(x_B, y_B) = (l, 0)$ and $(x_C, y_C) = (u, 0)$ vertices of the triangle are provided (Fig. 1). If we take the (1) formula into account, based on method proposed by Akyar et al. (2012), we can calculate the inradius (2), incenter (3) and rank (4) of the triangle using the following formulas:

$$r_{\tilde{A}} = \frac{(u-l)}{(u-l) + \sqrt{1+(u-m)^2} + \sqrt{1+(m-l)^2}} \tag{2}$$

$$I_{center}(x_{\tilde{A}}, y_{\tilde{A}}) = \frac{(u-l)(m,1) + \sqrt{1+(u-m)^2}(l,0) + \sqrt{1+(m-l)^2}(u,0)}{(u-l) + \sqrt{1+(u-m)^2} + \sqrt{1+(m-l)^2}} \tag{3}$$

$$RANK(\tilde{A}) = \left(x_{\tilde{A}} - \frac{1}{2}y_{\tilde{A}},\ 1 - y_{\tilde{A}},\ m\right) \tag{4}$$

We determine that the rank of the TFN is a triplet which depends on its incenter and peak point. We can rank them

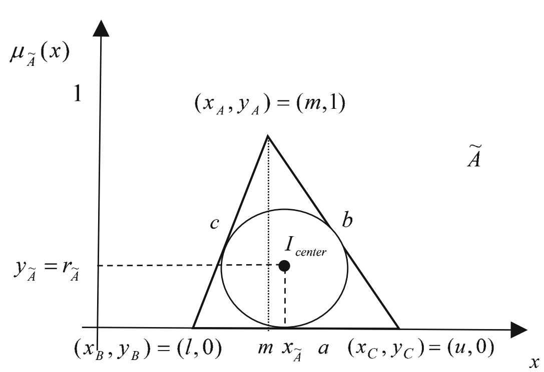

Fig. 1 Incircle, incenter and inradius of the TFN

Table 2 Linguistic variables for candidate evaluation

Linguistic variables	TFNs
Very high	(7, 9, 9)
High	(5, 7, 9)
Medium	(3, 5, 7)
Weak	(1, 3, 5)
Very weak	(1, 1, 3)

Table 3 Fuzzy decision matrix of voter V_1

Candidates	Criteria														
	C_1			C_2			C_3			C_4			C_5		
	(l,m,u)			(l,m,u)			(l,m,u)			(l,m,u)			(l,m,u)		
A_1	1	1	3	7	9	9	3	5	7	5	7	9	7	9	9
A_2	7	9	9	1	3	5	1	3	5	1	1	3	3	5	7
A_3	1	1	3	7	9	9	7	9	9	7	9	9	1	3	5
A_4	1	1	3	3	5	7	3	5	7	5	7	9	1	1	3
A_5	1	1	3	7	9	9	1	1	3	5	7	9	3	5	7
A_6	3	5	7	7	9	9	1	1	3	5	7	9	1	3	5
A_7	1	3	5	7	9	9	3	5	7	7	9	9	1	1	3
A_8	1	1	3	1	3	5	1	3	5	5	7	9	7	9	9
A_9	5	7	9	7	9	9	1	1	3	1	3	5	1	3	5
A_{10}	7	9	9	3	5	7	3	5	7	3	5	7	1	1	3
A_{11}	7	9	9	1	3	5	7	9	9	1	3	5	7	9	9
A_{12}	3	5	7	7	9	9	3	5	7	7	9	9	1	3	5
A_{13}	3	5	7	1	3	5	3	5	7	5	7	9	7	9	9
A_{14}	5	7	9	7	9	9	1	3	5	1	3	5	3	5	7
A_{15}	1	1	3	1	3	5	5	7	9	7	9	9	1	3	5
A_{16}	5	7	9	7	9	9	1	3	5	3	5	7	1	1	3
A_{17}	1	1	3	5	7	9	7	9	9	1	3	5	1	3	5
A_{18}	1	3	5	7	9	9	3	5	7	1	1	3	7	9	9
A_{19}	7	9	9	1	3	5	1	1	3	1	1	3	3	5	7
A_{20}	5	7	9	5	7	9	7	9	9	1	3	5	1	3	5

Table 4 Fuzzy decision matrix of voter V_2

Candidates	Criteria														
	C_1			C_2			C_3			C_4			C_5		
	(*l*,*m*,*u*)			(*l*,*m*,*u*)			(*l*,*m*,*u*)			(*l*,*m*,*u*)			(*l*,*m*,*u*)		
A_1	1	3	5	1	3	5	3	5	7	3	5	7	3	5	7
A_2	5	7	9	7	9	9	1	3	5	1	3	5	7	9	9
A_3	1	3	5	3	5	7	1	1	3	3	5	7	7	9	9
A_4	7	9	9	1	3	5	1	3	5	1	3	5	7	9	9
A_5	3	5	7	1	1	3	7	9	9	7	9	9	3	5	7
A_6	1	3	5	7	9	9	1	3	5	1	3	5	7	9	9
A_7	1	3	5	3	5	7	1	3	5	1	3	5	1	3	5
A_8	1	3	5	7	9	9	3	5	7	1	3	5	7	9	9
A_9	3	5	7	7	9	9	1	3	5	7	9	9	3	5	7
A_{10}	1	3	5	7	9	9	1	3	5	1	3	5	3	5	7
A_{11}	1	1	3	7	9	9	7	9	9	7	9	9	1	3	5
A_{12}	5	7	9	7	9	9	7	9	9	1	3	5	1	3	5
A_{13}	7	9	9	3	5	7	3	5	7	3	5	7	7	9	9
A_{14}	7	9	9	1	3	5	1	3	5	7	9	9	1	3	5
A_{15}	3	5	7	7	9	9	7	9	9	3	5	7	1	3	5
A_{16}	3	5	7	1	3	5	1	3	5	1	3	5	7	9	9
A_{17}	1	3	5	1	3	5	7	9	9	7	9	9	1	3	5
A_{18}	7	9	9	7	9	9	1	3	5	1	3	5	1	3	5
A_{19}	1	3	5	1	3	5	3	5	7	7	9	9	7	9	9
A_{20}	7	9	9	7	9	9	3	5	7	3	5	7	1	3	5

Table 5 Fuzzy decision matrix of voter V_3

Candidates	Criteria														
	C_1			C_2			C_3			C_4			C_5		
	(*l*,*m*,*u*)			(*l*,*m*,*u*)			(*l*,*m*,*u*)			(*l*,*m*,*u*)			(*l*,*m*,*u*)		
A_1	1	3	5	1	3	5	1	3	5	1	3	5	7	9	9
A_2	5	7	9	7	9	9	5	7	9	7	9	9	3	5	7
A_3	1	3	5	3	5	7	1	3	5	3	5	7	1	3	5
A_4	7	9	9	1	3	5	7	9	9	1	3	5	1	3	5
A_5	3	5	7	1	1	3	3	5	7	1	1	3	1	1	3
A_6	1	3	5	7	9	9	1	3	5	1	3	5	1	3	5
A_7	7	9	9	7	9	9	7	9	9	1	3	5	7	9	9
A_8	3	5	7	3	5	7	1	1	3	5	7	9	3	5	7
A_9	1	3	5	3	5	7	3	5	7	1	3	5	1	3	5
A_{10}	7	9	9	1	3	5	7	9	9	7	9	9	1	1	3
A_{11}	1	3	5	7	9	9	3	5	7	3	5	7	7	9	9
A_{12}	1	3	5	3	5	7	1	3	5	7	9	9	7	9	9
A_{13}	7	9	9	1	3	5	7	9	9	1	3	5	1	3	5
A_{14}	1	3	5	3	5	7	1	3	5	5	7	9	7	9	9
A_{15}	1	3	5	1	3	5	7	9	9	1	3	5	3	5	7
A_{16}	5	7	9	7	9	9	1	3	5	7	9	9	1	3	5
A_{17}	1	3	5	3	5	7	7	9	9	1	3	5	1	3	5
A_{18}	7	9	9	1	3	5	1	3	5	5	7	9	7	9	9
A_{19}	3	5	7	1	1	3	3	5	7	1	3	5	3	5	7
A_{20}	7	9	9	1	3	5	7	9	9	7	9	9	1	3	5

based on lexicographical ordering of TFNs ranking. For example, lexicographical ordering (where the symbol $<_L$ denotes the lexicographical order) of $\tilde{A} = (a_l, a_m, a_u)$ and $\tilde{B} = (b_l, b_m, b_u)$ TFN is as follows:$\tilde{A} = (a_l, a_m, a_u) <_L \tilde{B} = (b_l, b_m, b_u)$ if for first i, $a_i < b_i$, where a_i and b_i are different

As lexicographical ordering is a total order on R^n space, then the determined ordering relation demonstrates on the set of all TFNs.

4.1 Numerical experiment

Let's assume that 20 candidates were registered for parliamentary elections. Five criteria: indicators such as C_1—prestige in election area, C_2—education, C_3—government agency experience, C_4—professional competence, C_5—following in social media (activity), were determined for candidate selections.

Let's assume that in this case a set of 20 A_i $(i = 1, 2, \ldots, n)$ alternatives (candidates) is evaluated by five V_k decision makers (voters) in relation to five $C_j (j = 1, 2, \ldots, m)$ criteria.

Relevant linguistic variables are determined in order to evaluate alternatives in relation to each criterion. Decision makers use the TFN linguistic variables provided in Table 2 in order to evaluate alternatives in relation to criteria.

Decision matrixes based on evaluation of decision makers (voters) based on 20 alternatives in accordance with Step 1 and Step 2 are demonstrated in Tables 3, 4, 5, 6 and 7.

Aggregate fuzzy rating of candidates was calculated based on Step 3, and decision matrix is demonstrated in Table 8.

Aggregate fuzzy decision matrix normalized for benefit criteria in accordance with Step 4 is demonstrated in Table 9.

In accordance with Step 6, A^+ fuzzy positive ideal solution and A^- fuzzy negative ideal solution were determined based on normalized values as follows:

$$A^+ = \{1.000, 1.000, 1.000, 1.000, 1.000\},$$
$$A^- = \{0.171, 0.256, 0.111, 0.268, 0.220\}$$

Table 6 Fuzzy decision matrix of voter V_4

Candidates	Criteria														
	C_1			C_2			C_3			C_4			C_5		
	(l,m,u)			(l,m,u)			(l,m,u)			(l,m,u)			(l,m,u)		
A_1	7	9	9	1	3	5	7	9	9	1	3	5	1	3	5
A_2	1	3	5	5	7	9	1	3	5	5	7	9	7	9	9
A_3	7	9	9	1	3	5	7	9	9	1	3	5	3	5	7
A_4	1	3	5	7	9	9	1	3	5	7	9	9	1	3	5
A_5	7	9	9	1	3	5	1	3	5	1	3	5	1	3	5
A_6	1	3	5	5	7	9	7	9	9	5	7	9	7	9	9
A_7	7	9	9	1	3	5	3	5	7	3	5	7	1	3	5
A_8	1	3	5	7	9	9	1	3	5	3	5	7	3	5	7
A_9	7	9	9	3	5	7	1	3	5	1	3	5	7	9	9
A_{10}	1	3	5	5	7	9	7	9	9	7	9	9	1	3	5
A_{11}	1	3	5	1	3	5	1	3	5	1	3	5	5	7	9
A_{12}	1	3	5	1	3	5	1	3	5	7	9	9	1	3	5
A_{13}	5	7	9	5	7	9	7	9	9	1	3	5	7	9	9
A_{14}	7	9	9	7	9	9	7	9	9	7	9	9	1	3	5
A_{15}	1	3	5	3	5	7	1	3	5	1	3	5	5	7	9
A_{16}	1	3	5	1	3	5	1	3	5	1	3	5	1	3	5
A_{17}	5	7	9	5	7	9	7	9	9	7	9	9	1	3	5
A_{18}	1	3	5	1	3	5	3	5	7	3	5	7	7	9	9
A_{19}	7	9	9	7	9	9	1	3	5	7	9	9	3	5	7
A_{20}	3	5	7	3	5	7	1	1	3	3	5	7	7	9	9

Table 7 Fuzzy decision matrix of voter V_5

Candidates	Criteria														
	C_1			C_2			C_3			C_4			C_5		
	(l,m,u)			(l,m,u)			(l,m,u)			(l,m,u)			(l,m,u)		
A_1	7	9	9	7	9	9	1	3	5	5	7	9	1	3	5
A_2	3	5	7	3	5	7	7	9	9	1	3	5	5	7	9
A_3	1	3	5	3	5	7	7	9	9	1	3	5	1	3	5
A_4	7	9	9	7	9	9	3	5	7	5	7	9	1	3	5
A_5	3	5	7	3	5	7	3	5	7	1	3	5	5	7	9
A_6	1	3	5	3	5	7	1	3	5	1	3	5	1	3	5
A_7	7	9	9	1	3	5	7	9	9	1	3	5	1	3	5
A_8	1	3	5	7	9	9	1	3	5	3	5	7	5	7	9
A_9	7	9	9	7	9	9	1	3	5	1	3	5	1	3	5
A_{10}	3	5	7	3	5	7	5	7	9	1	3	5	5	7	9
A_{11}	1	3	5	3	5	7	1	3	5	1	3	5	1	3	5
A_{12}	7	9	9	3	5	7	5	7	9	5	7	9	1	3	5
A_{13}	1	3	5	7	9	9	1	3	5	1	3	5	5	7	9
A_{14}	7	9	9	1	3	5	5	7	9	5	7	9	5	7	9
A_{15}	7	9	9	7	9	9	1	3	5	1	3	5	1	3	5
A_{16}	3	5	7	7	9	9	1	3	5	1	3	5	1	3	5
A_{17}	1	3	5	3	5	7	5	7	9	5	7	9	5	7	9
A_{18}	7	9	9	3	5	7	1	3	5	1	3	5	1	3	5
A_{19}	1	3	5	1	3	5	5	7	9	7	9	9	7	9	9
A_{20}	1	3	5	7	9	9	1	3	5	3	5	7	3	5	7

In accordance with Steps 8 and 9, A_i candidates are ranked in descending order based on the values of CI_i closeness index and demonstrated in Table 10.

As seen from Table 10, in this case A_{14} has the highest rank based on voters' opinion.

In the article, candidates' aggregate fuzzy rating is ranked using the TFNs ranking method proposed by Akyar et al. (2012) in accordance with Step 3 and obtained results are compared.

For this purpose, (2) formula is used to calculate the inradius of each TFN based on aggregate fuzzy decision matrix of the candidates shown in Table 2 and the result is demonstrated in Table 11.

Incenter of the TFNs as shown in Table 12 is calculated using formulas (3) and (4), and rank of the TFNs is calculated and shown in Table 13.

We can calculate the resultant rank of the TFNs in relation to all criteria using positional ranking approach (POS) with the following formula (Aliguliyev 2009):

$$\text{Resultant rank} = \sum_{t=1}^{\eta} \frac{(\eta - t + 1) r_t}{\eta}$$

where r_t denotes the number of times the method appears in the t-th rank and η is the number of alternatives.

Results obtained using fuzzy TOPSIS and TFNs methods are shown in Table 14.

Many rank aggregation methods and their modified options are proposed in the literature. Intuitiveness and convenience of the methods have allowed their wide application in practice. Aggregation rank proposed by Borda, which is one of the simplest and most common methods, is calculated based on arithmetic mean of completely ranked lists (Lin 2010). Interestingly, Borda methods and their different variants are still used during elections in some countries (Lin 2010; Emerson 2016). Fuzzy TOPSIS and TFNs resultant (aggregate) rank is calculated based on arithmetic mean (ARM), geometric mean (GEM) and harmonic mean (HARM) methods and shown in Table 14.

The article proposes two approaches in order to determine the best alternative based on compromise solution.

First approach This approach is based on calculation of Euclidean D_{ik}^{+} and D_{ik}^{-} distance for each voter (decision maker) in accordance with Step 7, instead of calculating aggregate fuzzy rating for alternatives shown in Step 3. In

Table 8 Creating aggregate fuzzy decision matrix

Candidates	Criteria														
	C_1			C_2			C_3			C_4			C_5		
	(*l*,*m*,*u*)			(*l*,*m*,*u*)			(*l*,*m*,*u*)			(*l*,*m*,*u*)			(*l*,*m*,*u*)		
A_1	3.400	5.000	6.200	3.400	5.400	6.600	3.000	5.000	6.600	3.000	5.000	7.000	3.800	5.800	7.000
A_2	4.200	6.200	7.800	4.600	6.600	7.800	3.000	5.000	6.600	3.000	4.600	6.200	5.000	7.000	8.200
A_3	2.200	3.800	5.400	3.400	5.400	7.000	4.600	6.200	7.000	3.000	5.000	6.600	2.600	4.600	6.200
A_4	4.600	6.200	7.000	3.800	5.800	7.000	3.000	5.000	6.600	3.800	5.800	7.400	2.200	3.800	5.400
A_5	3.400	5.000	6.600	2.600	3.800	5.400	3.000	4.600	6.200	3.000	4.600	6.200	2.600	4.200	6.200
A_6	1.400	3.400	5.400	5.800	7.800	8.600	2.200	3.800	5.400	2.600	4.600	6.600	3.400	5.400	6.600
A_7	4.600	6.600	7.400	3.800	5.800	7.000	4.200	6.200	7.400	2.600	4.600	6.200	2.200	3.800	5.400
A_8	1.400	3.000	5.000	5.000	7.000	7.800	1.400	3.000	5.000	3.400	5.400	7.400	5.000	7.000	8.200
A_9	4.600	6.600	7.800	5.400	7.400	8.200	1.400	3.000	5.000	2.200	4.200	5.800	2.600	4.600	6.200
A_{10}	3.800	5.800	7.000	3.800	5.800	7.400	4.600	6.600	7.800	3.800	5.800	7.000	2.200	3.400	5.400
A_{11}	2.200	3.800	5.400	3.800	5.800	7.000	3.800	5.800	7.000	2.600	4.600	6.200	4.200	6.200	7.400
A_{12}	3.400	5.400	7.000	4.200	6.200	7.400	3.400	5.400	7.000	5.400	7.400	8.200	2.200	4.200	5.800
A_{13}	4.600	6.600	7.800	3.400	5.400	7.000	4.200	6.200	7.400	2.200	4.200	6.200	5.400	7.400	8.200
A_{14}	5.400	7.400	8.200	3.800	5.800	7.000	3.000	5.000	6.600	5.000	7.000	8.200	3.400	5.400	7.000
A_{15}	2.600	4.200	5.800	3.800	5.800	7.000	4.200	6.200	7.400	2.600	4.600	6.200	2.200	4.200	6.200
A_{16}	3.400	5.400	7.400	4.600	6.600	7.400	1.000	3.000	5.000	2.600	4.600	6.200	2.200	3.800	5.400
A_{17}	1.800	3.400	5.400	3.400	5.400	7.400	6.600	8.600	9.000	4.200	6.200	7.400	1.800	3.800	5.800
A_{18}	4.600	6.600	7.400	3.800	5.800	7.000	1.800	3.800	5.800	2.200	3.800	5.800	4.600	6.600	7.400
A_{19}	3.800	5.800	7.000	2.200	3.800	5.400	2.600	4.200	6.200	4.600	6.200	7.000	4.600	6.600	7.800
A_{20}	4.600	6.600	7.800	4.600	6.600	7.800	3.800	5.400	6.600	3.400	5.400	7.000	2.600	4.600	6.200

this case, both distances are aggregated as group distance for each voter using different operators and we can calculate CI_i closeness index for each alternative. Table 15 shows closeness index and alternatives' ranking using different aggregation methods.

Second approach In this approach, CI_i closeness index is calculated for each alternative based on Euclidean D_{ik}^{+} and D_{ik}^{-} distances for each voter (decision maker) and resultant index and rank are calculated using aggregation operators. Table 16 shows resultant closeness index and rank using aggregation operators for each alternative.

Let's use a compromise solution approach in order to compare the rank lists obtained using different methods and determine the optimal solution option. If the following condition is met, ranking is considered as the optimal compromise solution at minimal value of CI_i closeness index (Alguliyev et al. 2015). In the ranking, A_1 has the first acceptable advantage, and if $(CI(A_2) - CI(A_1))/(CI(A_n) - CI(A_1)) \geq 1/(n-1)$ condition is met, it is considered the compromise solution,where A_1 is the best alternative A_2 is the alternative on the second position of the ranking list and n is the number of alternatives. CI_i measure of rank lists shown in Table 14, 15 and 16 was calculated using the compromise solution approach and is shown in Table 17.

If we compare the ranks obtained using both methods and ARM, GEM, HARM aggregation operators and review their correlations, it is apparent that these ranks correlate, but there are obvious differences on different rank positions. It is well known that alternatives' ranking based on the TOPSIS method is carried out in relation to ideal solution. As with many issues in real life, there is no ideal solution option in the election process, so alternatives can be compared only among themselves. From this point of view, if we compare both methods, the application of the TFNs method will give a better result. Ranking of criteria based on different criteria, and ultimately, the final ranking based on these ranks reflects a more realistic image. There are some advantages in applying the ranking of fuzzy numbers. Ranking process is quite simple and efficient in terms of calculation and comparison. This makes the application of the TFNs detection method more effective.

In addition, ranking of alternatives using modified fuzzy TOPSIS method based on aggregation of Euclidean D_{ik}^{+} and D_{ik}^{-} distances in accordance with the first approach provided in the article provides better result as shown in

Table 9 Creating aggregate fuzzy decision matrix

Candidates	Criteria														
	C_1			C_2			C_3			C_4			C_5		
	(l,m,u)			(l,m,u)			(l,m,u)			(l,m,u)			(l,m,u)		
A_1	0.415	0.610	0.756	0.395	0.628	0.767	0.333	0.556	0.733	0.366	0.610	0.854	0.463	0.707	0.854
A_2	0.512	0.756	0.951	0.535	0.767	0.907	0.333	0.556	0.733	0.366	0.561	0.756	0.610	0.854	1.000
A_3	0.268	0.463	0.659	0.395	0.628	0.814	0.511	0.689	0.778	0.366	0.610	0.805	0.317	0.561	0.756
A_4	0.561	0.756	0.854	0.442	0.674	0.814	0.333	0.556	0.733	0.463	0.707	0.902	0.268	0.463	0.659
A_5	0.415	0.610	0.805	0.302	0.442	0.628	0.333	0.511	0.689	0.366	0.561	0.756	0.317	0.512	0.756
A_6	0.171	0.415	0.659	0.674	0.907	1.000	0.244	0.422	0.600	0.317	0.561	0.805	0.415	0.659	0.805
A_7	0.561	0.805	0.902	0.442	0.674	0.814	0.467	0.689	0.822	0.317	0.561	0.756	0.268	0.463	0.659
A_8	0.171	0.366	0.610	0.581	0.814	0.907	0.156	0.333	0.556	0.415	0.659	0.902	0.610	0.854	1.000
A_9	0.561	0.805	0.951	0.628	0.860	0.953	0.156	0.333	0.556	0.268	0.512	0.707	0.317	0.561	0.756
A_{10}	0.463	0.707	0.854	0.442	0.674	0.860	0.511	0.733	0.867	0.463	0.707	0.854	0.268	0.415	0.659
A_{11}	0.268	0.463	0.659	0.442	0.674	0.814	0.422	0.644	0.778	0.317	0.561	0.756	0.512	0.756	0.902
A_{12}	0.415	0.659	0.854	0.488	0.721	0.860	0.378	0.600	0.778	0.659	0.902	1.000	0.268	0.512	0.707
A_{13}	0.561	0.805	0.951	0.395	0.628	0.814	0.467	0.689	0.822	0.268	0.512	0.756	0.659	0.902	1.000
A_{14}	0.659	0.902	1.000	0.442	0.674	0.814	0.333	0.556	0.733	0.610	0.854	1.000	0.415	0.659	0.854
A_{15}	0.317	0.512	0.707	0.442	0.674	0.814	0.467	0.689	0.822	0.317	0.561	0.756	0.268	0.512	0.756
A_{16}	0.415	0.659	0.902	0.535	0.767	0.860	0.111	0.333	0.556	0.317	0.561	0.756	0.268	0.463	0.659
A_{17}	0.220	0.415	0.659	0.395	0.628	0.860	0.733	0.956	1.000	0.512	0.756	0.902	0.220	0.463	0.707
A_{18}	0.561	0.805	0.902	0.442	0.674	0.814	0.200	0.422	0.644	0.268	0.463	0.707	0.561	0.805	0.902
A_{19}	0.463	0.707	0.854	0.256	0.442	0.628	0.289	0.467	0.689	0.561	0.756	0.854	0.561	0.805	0.951
A_{20}	0.561	0.805	0.951	0.535	0.767	0.907	0.422	0.600	0.733	0.415	0.659	0.854	0.317	0.561	0.756

Table 10 Ranking of the candidates

Candidates	CI_i	Rank_{ARM}
A_1	0.501	12
A_2	0.578	3
A_3	0.474	17
A_4	0.511	10
A_5	0.430	20
A_6	0.469	18
A_7	0.517	8
A_8	0.485	15
A_9	0.490	14
A_{10}	0.534	6
A_{11}	0.496	13
A_{12}	0.548	5
A_{13}	0.582	2
A_{14}	0.596	1
A_{15}	0.475	16
A_{16}	0.439	19
A_{17}	0.528	7
A_{18}	0.509	11
A_{19}	0.516	9
A_{20}	0.556	4

Table 17, and we can consider the FTOPSIS $(\text{DIST})_{\text{ARM}}$ rank where CI equals to 0.089 as the optimal compromise solution.

It is known that personnel selection and evaluation are a MCDM problem and depend on many criteria. In this research, fuzzy TOPSIS and TFNs ranking methods are used to address the selection and evaluation of candidates in the election process. In comparison with criteria based on both methods, the rating of the candidates against the selected criteria provides the linguistic variables expressed in the TFNs. A numerical experiment was conducted based on the proposed models, and the results were compared. The results show that the fuzzy MCDM application is practical and useful in selecting staff. The proposed approach can be used to evaluate candidates based on criteria selected in different election processes in similar cases.

Table 11 TFNs with its inradius

Candidates	$r_{\tilde{A}}$				
	C_1	C_2	C_3	C_4	C_5
A_1	0.448	0.457	0.466	0.472	0.457
A_2	0.466	0.457	0.466	0.459	0.457
A_3	0.459	0.466	0.431	0.466	0.466
A_4	0.431	0.457	0.466	0.466	0.459
A_5	0.459	0.448	0.459	0.459	0.466
A_6	0.472	0.443	0.459	0.472	0.457
A_7	0.443	0.457	0.457	0.466	0.459
A_8	0.466	0.443	0.466	0.472	0.457
A_9	0.457	0.443	0.466	0.466	0.466
A_{10}	0.457	0.466	0.457	0.457	0.457
A_{11}	0.459	0.457	0.457	0.466	0.457
A_{12}	0.466	0.457	0.466	0.443	0.466
A_{13}	0.457	0.466	0.457	0.472	0.443
A_{14}	0.443	0.457	0.466	0.457	0.466
A_{15}	0.459	0.457	0.457	0.466	0.472
A_{16}	0.472	0.443	0.472	0.466	0.459
A_{17}	0.466	0.472	0.420	0.457	0.472
A_{18}	0.443	0.457	0.472	0.466	0.443
A_{19}	0.457	0.459	0.466	0.431	0.457
A_{20}	0.457	0.457	0.448	0.466	0.466

5 Conclusion

In digital age, human resources are considered as the main strategic resource of the government. Nowadays, separate government agencies, the private sector and companies face very serious problems when selecting competent and motivated personnel in line with relevant requirements. Selection of qualified personnel is of great importance for companies. In particular, this gives itself a more vivid impetus in a situation where market competition is rising. In this regard, decision makers pay great attention to the selection of qualified personnel in the process of recruitment and selection of candidates.

Globalization, social, economic and political processes in the world are of great importance to the selection of qualified personnel at the government level and their appointment to responsible positions. Obviously, the effective functioning of governments is directly dependent on human resources and the participation of qualified, competent people in governance is a matter of national importance. From this point of view, selection of competent candidates suitable to perform state-run tasks in the election process and criteria and factors to be considered in the selection process are topical issues. In the presidential election or the parliamentary elections, selection of the candidates and results of the election always lead to broad

Table 12 TFNs with its incenter

Candidates	$I_{center}(x_{\tilde{A}}, y_{\tilde{A}})$									
	C_1		C_2		C_3		C_4		C_5	
	$x_{\tilde{A}}$	$y_{\tilde{A}}$	$x_{\tilde{A}}$	$y_{\tilde{A}}$	$x_{\tilde{A}}$	$y_{\tilde{A}}$	$x_{\tilde{A}}$	$y_{\tilde{A}}$	$x_{\tilde{A}}$	$y_{\tilde{A}}$
A_1	4.962	0.448	5.337	0.457	4.975	0.466	5.000	0.472	5.737	0.457
A_2	6.175	0.466	6.537	0.457	4.975	0.466	4.600	0.459	6.937	0.457
A_3	3.800	0.459	5.375	0.466	6.103	0.431	4.975	0.466	4.575	0.466
A_4	6.103	0.431	5.737	0.457	4.975	0.466	5.775	0.466	3.800	0.459
A_5	5.000	0.459	3.838	0.448	4.600	0.459	4.600	0.459	4.225	0.466
A_6	3.400	0.472	7.678	0.443	3.800	0.459	4.600	0.472	5.337	0.457
A_7	6.478	0.443	5.737	0.457	6.137	0.457	4.575	0.466	3.800	0.459
A_8	3.025	0.466	6.878	0.443	3.025	0.466	5.400	0.472	6.937	0.457
A_9	6.537	0.457	7.278	0.443	3.025	0.466	4.175	0.466	4.575	0.466
A_{10}	5.737	0.457	5.775	0.466	6.537	0.457	5.737	0.457	3.463	0.457
A_{11}	3.800	0.459	5.737	0.457	5.737	0.457	4.575	0.466	6.137	0.457
A_{12}	5.375	0.466	6.137	0.457	5.375	0.466	7.278	0.443	4.175	0.466
A_{13}	6.537	0.457	5.375	0.466	6.137	0.457	4.200	0.472	7.278	0.443
A_{14}	7.278	0.443	5.737	0.457	4.975	0.466	6.937	0.457	5.375	0.466
A_{15}	4.200	0.459	5.737	0.457	6.137	0.457	4.575	0.466	4.200	0.472
A_{16}	5.400	0.472	6.478	0.443	3.000	0.472	4.575	0.466	3.800	0.459
A_{17}	3.425	0.466	5.400	0.472	8.380	0.420	6.137	0.457	3.800	0.472
A_{18}	6.478	0.443	5.737	0.457	3.800	0.472	3.825	0.466	6.478	0.443
A_{19}	5.737	0.457	3.800	0.459	4.225	0.466	6.103	0.431	6.537	0.457
A_{20}	6.537	0.457	6.537	0.457	5.362	0.448	5.375	0.466	4.575	0.466

Table 13 $RANK(\tilde{A})$ rank of TFNs

Candidates	$RANK(\tilde{A})$				
	C_1	C_2	C_3	C_4	C_5
A_1	14	18	10	9	7
A_2	7	4	10	11	2
A_3	16	16	6	10	10
A_4	8	9	10	5	16
A_5	13	19	14	11	13
A_6	19	1	16	13	9
A_7	5	9	3	14	16
A_8	20	3	18	7	2
A_9	2	2	18	19	10
A_{10}	9	8	2	6	20
A_{11}	16	9	7	14	6
A_{12}	12	7	8	1	15
A_{13}	2	16	3	18	1
A_{14}	1	9	10	2	8
A_{15}	15	9	3	14	14
A_{16}	11	6	20	14	16
A_{17}	18	15	1	3	19
A_{18}	5	9	17	20	5
A_{19}	9	20	15	4	4
A_{20}	2	4	9	8	10

discussions. Selection of candidates or suitability of the appointed person to the office is always a matter of government interest and open for discussion. It is therefore suggested in the study that the application of multi-criteria assessment for the selection of a competent candidate will allow making more effective decisions. Criteria for the selection of candidates have been studied in the research, and the evaluation of candidates will be reviewed using the modified fuzzy MCDM model. Fuzzy TOPSIS and TFNs ranking methods and different aggregation methods are used rank the candidates based on selected criteria. The linguistic variables expressed by TFNs were used for the evaluation of candidates in the numerical experiment, based on the criteria such as influence in the election region, education, government agency experience, professional competence and social media following (activity). With the application of both methods, candidates were ranked and correlation of obtained results was reviewed. The obtained results show that the TFNs ranking method is the most effective one. Additionally, the modified fuzzy TOPSIS method proposed in the article allows for better results and can be considered as an optimal compromise solution. As a future research direction, improvement and application of hybrid MCDM methods will be considered in order to further improve the results obtained.

Table 14 Candidate ranking based on fuzzy TOPSIS and TFNs methods

Candidates	Rank						
	Fuzzy $\text{TOPSIS}_{\text{ARM}}$	Fuzzy $\text{TOPSIS}_{\text{GEM}}$	Fuzzy $\text{TOPSIS}_{\text{HARM}}$	TFNs_{POS}	TFNs_{ARM}	TFNs_{GEM}	$\text{TFNs}_{\text{HARM}}$
A_1	12	15	14	18	16	18	18
A_2	3	3	3	3	3	4	8
A_3	17	18	19	16	16	17	17
A_4	10	13	16	8	8	13	15
A_5	20	20	20	20	20	20	20
A_6	18	14	10	16	16	11	5
A_7	8	10	11	7	7	10	11
A_8	15	8	7	9	9	7	9
A_9	14	9	8	10	10	6	6
A_{10}	6	7	9	6	6	9	10
A_{11}	13	16	15	11	11	16	16
A_{12}	5	4	5	5	5	5	4
A_{13}	2	2	2	4	4	2	1
A_{14}	1	1	1	1	1	1	2
A_{15}	16	17	17	13	13	15	13
A_{16}	19	19	18	19	19	19	19
A_{17}	7	6	4	15	14	8	3
A_{18}	11	12	12	14	14	14	14
A_{19}	9	11	13	12	11	12	12
A_{20}	4	5	6	2	2	3	7

Table 15 Ranking of Euclidean D_{ik}^{+} and D_{ik}^{-} distances of the voters based on aggregation

Candidates	Rank					
	$CI_{DISTANCE}$	FTOPSIS $(DIST)_{ARM}$	$CI_{DISTANCE}$	FTOPSIS $(DIST)_{GEM}$	$CI_{DISTANCE}$	FTOPSIS $(DIST)_{HARM}$
A_1	0.464	12	0.462	12	0.459	12
A_2	0.520	3	0.523	3	0.526	2
A_3	0.446	18	0.443	18	0.439	18
A_4	0.473	9	0.473	8	0.473	8
A_5	0.416	20	0.412	20	0.408	19
A_6	0.446	17	0.443	17	0.440	17
A_7	0.472	10	0.469	11	0.466	11
A_8	0.459	14	0.458	13	0.458	13
A_9	0.458	15	0.456	14	0.453	14
A_{10}	0.487	7	0.486	7	0.485	7
A_{11}	0.460	13	0.454	15	0.446	16
A_{12}	0.501	5	0.501	5	0.500	5
A_{13}	0.522	2	0.523	2	0.525	3
A_{14}	0.532	1	0.534	1	0.536	1
A_{15}	0.448	16	0.448	16	0.447	15
A_{16}	0.420	19	0.414	19	0.407	20
A_{17}	0.489	6	0.490	6	0.491	6
A_{18}	0.470	11	0.470	10	0.469	10
A_{19}	0.474	8	0.472	9	0.470	9
A_{20}	0.502	4	0.502	4	0.501	4

Table 16 Ranking of alternatives in relation to aggregation of closeness indexes

Candidates	Rank					
	CI_{ARM}	FTOPSIS $(CI)_{ARM}$	CI_{GEM}	FTOPSIS $(CI)_{GEM}$	CI_{HARM}	FTOPSIS $(CI)_{HARM}$
A_1	0.463	12	0.457	13	0.452	12
A_2	0.522	3	0.516	3	0.509	3
A_3	0.444	18	0.438	17	0.433	16
A_4	0.473	8	0.469	8	0.466	9
A_5	0.415	20	0.407	20	0.398	19
A_6	0.445	17	0.434	18	0.423	18
A_7	0.471	10	0.458	11	0.444	14
A_8	0.459	13	0.458	12	0.457	10
A_9	0.457	14	0.452	14	0.446	13
A_{10}	0.486	7	0.484	7	0.482	6
A_{11}	0.456	15	0.443	16	0.429	17
A_{12}	0.501	5	0.497	5	0.492	5
A_{13}	0.523	2	0.520	2	0.516	2
A_{14}	0.533	1	0.528	1	0.524	1
A_{15}	0.448	16	0.445	15	0.442	15
A_{16}	0.418	19	0.407	19	0.395	20
A_{17}	0.490	6	0.485	6	0.480	7
A_{18}	0.470	11	0.468	9	0.466	8
A_{19}	0.473	9	0.464	10	0.455	11
A_{20}	0.502	4	0.500	4	0.498	4

Table 17 *CI* measure for rank lists based on compromise solution approach

	$FTOPSIS_{ARM}$	$FTOPSIS_{GEM}$	$FTOPSIS_{HARM}$	$TFNs_{POS}$	$TFNs_{ARM}$	$TFNs_{GEM}$	$TFNs_{HARM}$
CI	0.084 >	0.030 <	0.004 <	0.075 >	0.075 >	0.017 <	0.015 <
$1/(n-1) = 0.053$	[+]	[−]	[−]	[+]	[+]	[−]	[−]

	$FTOPSIS\ (DIST)_{ARM}$	$FTOPSIS\ (DIST)_{GEM}$	$FTOPSIS\ (DIST)_{HARM}$	$FTOPSIS\ (CI)_{ARM}$	$FTOPSIS\ (CI)_{GEM}$	$FTOPSIS\ (CI)_{HARM}$
CI	0.089 >	0.086 >	0.081 >	0.084 >	0.072 >	0.060 >
$1/(n-1) = 0.053$	[+]	[+]	[+]	[+]	[+]	[+]

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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