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A NEW SOFTWARE DEVELOPMENT FOR FUZZY MULTICRITERIA DECISION-MAKING

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Abstract. In this paper, software for Fuzzy Multiple Criteria Decision Making (FMCDM) problems has been developed and tested on two real problems. FMCDM methods are widely used when imprecise data or linguistic variables exist in the problem. Using FMCDM methods may help improve decision-making problems and lead to more accurate models. Although these methods are more involved in terms of computing due to fuzzy calculations in MCDM algorithms, fuzziness offers advantages over classical algorithms. Thus appropriate software is of great importance in applying FMCDM methods. The major aim of this study is to develop software and to test it on two real military problems which are solved by an ideal points algorithm and an outranking method. The results and outputs are discussed with sensitivity analyses.

Keywords: FMCDM, ideal points, outranking, software.

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1. Introduction

Multicriteria decision-making (MCDM) problems arise in situations where a (group of) decision-maker(s) faces a problem of choosing the best alternative among several possible alternatives. The main steps of MCDM can be stated as; establishing system evaluation criteria that relate system capabilities to goals, developing alternative systems for attaining the goals, evaluating alternatives in terms of the selected criteria, applying a normative multicriteria analysis method and accepting one alternative as "optimal" (Opricovic and Tzeng 2004).

In general, the decision-makers (DMs) have to consider both quantitative and qualitative assessments of the criteria in evaluating the considered alternatives. Classical MCDM problems usually present judgments as crisp numerical values and they need to evaluate the

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performance of alternatives versus each criterion. On the other hand, information about the alternatives is often imprecise or the DMs can only give approximate, incomplete or not well-defined information. Another point to be taken into account is that some criteria may be subjective. To deal with these problems, fuzzy set theory has been frequently applied to MCDM problems. Some of these MCDM methods are TOPSIS (Hwang and Yoon 1981; Ashtiani *et al.* 2008), VIKOR (Opricovic and Tzeng 2004, 2007), PROMETHEE (Brans *et al.* 1984; Olson 2001) and ELECTRE (Benayoun *et al.* 1966; Wang and Triantaphyllou 2008).

Fuzzy MCDM (FMCDM) methods may help resolve some difficulties frequently encountered in decision-making. It mainly aims to reduce the effects of imprecision like human judgment and preferences while searching for the optimal decision (Slowinski 1998). On the other hand, the application of FMCDM methods may yield some problems. Even for relatively small problems, the necessary computations are quite time-consuming and may lead to errors. Hence it is important to have appropriate software for applications of such methods. For this reason software is developed to enable the application of two special FMCDM methods.

Since the two problems considered for applying and testing the software are of military origin, the importance of such problems and their nature will be briefly pointed out. In military services, decision-making is mostly related to budget and logistic planning, mission tasks, simulation of roadmaps, and preparation for wars. Especially in wartimes, capacities of the armed forces culminate. The fact that warfare is a fundamentally competitive activity having heavy influence on the kind of weapon systems required, the analyses are needed to design them (Washburn 1994).

The two specific problems that are considered in this study are the military staff assignment and the sniper gun selection problems. In Turkey, military staff is assigned to geographical regions rotationally. There exists seven main regions and each region consists of different numbers of city centre. It is an important assignment that the staff is to be assigned to her/his preferred city centre, which is assumed to be the optimal alternative for him. The second problem is also an important problem since in the military services, the power and utility of guns are crucial in critical combat situations. In fact, the equipment to be used depends mainly on the mission.

The main focus of this study is the development of software to be used in the implementation of two FMCDM methods and its application to two real problems. The problems considered also show how the software may help DMs to infer some interesting observations. It will be of great importance in real life applications and in consideration of alternative scenarios.

2. Fuzzy multiple criteria decision-making

Fuzzy models are alternative approaches in cases of ill-defined data or lack of knowledge. FMCDM is generally based on fuzziness of MCDM theories where it is a tool that aids DMs to manage the uncertainty of their, sometimes subjective, judgments. Actually, when DMs evaluate an exact judgment by crisp numbers rather than qualitative expressions, MCDM uses fuzzy evaluations and presents the appropriateness of alternatives against each other.

FMCDM has an advantage of not complicating the problem due to neither the number of criteria nor the number of alternatives. Besides, the results are both realistic and satisfactory (Liang 1999; Lai and Hwang 1994). FMCDM is applied mostly in situations where every DM has his/her own rankings due to his/her goals, and where each individual DM's evaluations are based on different resources. Both ways are away from certainty and the decisions are evaluated as fuzzy (Klir and Yuan 1995).

FMCDM methods have been studied extensively in the literature. Roubens (1997) presented decision studies done in fuzzy environment. His work included MCDM problems as well. Liang (1999) introduced an algorithm based on positive and negative ideal solutions of the problem. In his approach, DMs firstly determine the criteria and alternatives individually. He achieved the ideal and anti-ideal alternatives, and then calculated the distances of each alternative from these ideal solutions. The closest alternative to the positive ideal solution and the farthest to the negative ideal solution is determined as the optimal alternative. Due to the fuzziness of weights of criteria, ratings and decision matrix are achieved in fuzzy environment. Ding and Liang (2005) used FMCDM in selecting partners in strategic alliances for liner shipping. The study is based on Liang's (1999) algorithm and combined with graded mean and entropy. For some other FMCDM methods we refer the reader to Kuo *et al.* (2006), Chang *et al.* (2007) and Yang *et al.* (2008), among others.

Aouam *et al.* (2003) introduced a FMCDM method based on a fuzzy outranking relation using triangular fuzzy numbers. In this approach, the DMs provide veto values and fuzzy threshold values for each criterion. For details on the outranking relation see Roy (1977), for outranking methods – Bouyssou (2001), and for some recent developments on outranking methods see (Fernandez and Leyva 2004).

One of the recent studies on FMCDM is Chiou *et al.* (2005), where fuzzy numbers are used in fuzzy weights for development of sustainable strategies and the study used fuzzy hierarchical analysis for obtaining the weights. Although FMCDM methods are applied in many decision-making problems, it should be noted that they are based on comparing and ranking fuzzy numbers. The ranking process is not so straight-forward, yet it may involve considerable calculations. In addition, as is known, they can lead to inconsistent results.

2.1. Fuzzy numbers

We use triangular and trapezoidal fuzzy numbers in the FMCDM methods. Therefore before presenting these methods, we give some basic definitions of fuzzy numbers.

Definition 1. Let A be a fuzzy set and $\mu_A(x)$ the membership function of x in set A. For $A=\{(x;\, \mu_A(x)) \mid x \in X\}$ set A is defined as:

$$A = \mu_A(x_1)/\, x_1 + \mu_A(x_2)/\, x_2 \ldots + \mu_A(x_n)/\, x_n = \sum_{i=1}^{n} \mu_A(x_i)\, /\, x_i. \tag{1}$$

In the fuzzy theory, there is not a certain way for determining the membership function. Membership function is determined by considering both the problem and structure of fuzzy number (Lai and Hwang 1994).

Definition 2. Let *A* be a fuzzy set and $\mu_A(x)$ be the membership function for $x \in A$, if $\mu_A(x)$ is defined as below:

$$\mu_A(x) = \begin{cases} \dfrac{(x-a)}{(b-a)}, & a \le x < b \\ 1, & b \le x \le c \\ \dfrac{(d-x)}{(d-c)}, & c < x \le d \end{cases} \tag{2}$$

then *x* is a trapezoidal fuzzy number (Fig. 1). For $b = c$, *x* is a triangular fuzzy number (Klir and Yuan 1995).

In this study, both trapezoidal and triangular numbers are used when defining the problems. Any trapezoidal fuzzy number will be denoted by <*a*, *b*, *c*, *d*> and any triangular fuzzy number by <*a*, *b*, *d*>.

Denoting the set of alternatives by *A*, the MCDM approaches essentially consist of building and aggregating performances related to the alternatives in *A* or partial binary valued preference relations in $A \times A$ with respect to each attribute (Roubens 1997).

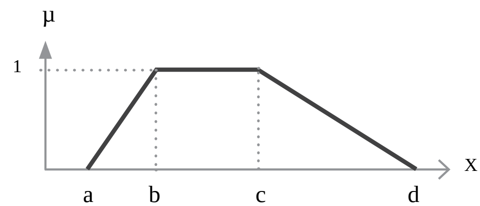


Fig. 1. Trapezoidal fuzzy number; <*a*, *b*, *c*, *d*>

2.2. FMCDM methods used

Two different FMCDM methods, each having their own strengths and computational difficulties, are used. The Ideal and Anti-Ideal Concepts Algorithm, presented by Liang (1999), is applied to the personnel assignment problem and the method proposed by Aouam *et al.* (2003) is applied to the sniper gun selection problem.

2.2.1. The ideal and anti-ideal concept algorithm

The algorithm calculates the degrees of appropriateness of each alternative versus each criterion and investigates the distance of this degree from the Ideal and negative ideal points. The most relevant alternative to the positive ideal solution with the farthest to the negative ideal point is considered to be the optimal alternative.

Decision-makers ($\mathbf{DM_t}$, $t = 1, 2, \ldots, n$), alternatives ($\boldsymbol{a_i}$, $i = 1, 2, \ldots, m$), criteria ($\mathbf{C_j}$, $j = 1, 2, \ldots k$) and weights ($\tilde{\mathbf{W}}_\mathbf{j}$, $j = 1, 2, \ldots k$) are defined with respect to pre-determined weights and scales. The aggregated fuzzy ratings $[\tilde{\mathbf{X}}_\mathbf{ij}]$ are calculated. Then the weighted appropriateness decision matrix $[\tilde{\mathbf{D}}_\mathbf{ij}]$ is calculated based on the rating scales and weights. Briefly, the algorithm is given as below.

Step 1: Determination of Problem Inputs:
Decision-makers $\mathbf{DM_t}$, alternatives $\boldsymbol{a_i}$, and criteria $\mathbf{C_j}$ are determined.

Step 2: Classification of Criteria:
Criteria are classified as objective and subjective.

Step 3: Evaluation of Alternatives and Determination of Criteria Weights:
Rating scale sets for weights and the appropriateness of alternatives for each criterion are determined. Then fuzzy weights for criteria, $\tilde{\mathbf{W}}_{\mathbf{j}}$, are defined with respect to pre-determined weights and scales.

Step 4: Calculation of Fuzzy Decision Matrix:
On the basis of rating scales and weights, aggregated fuzzy ratings $[\tilde{\mathbf{X}}_{\mathbf{ij}}]$ are calculated. Weighted appropriateness decision matrix $[\tilde{\mathbf{D}}_{\mathbf{ij}}]$ is constructed for subjective and objective criteria.

Step 6: Calculation of Ideals:
Positive and negative ideal solutions ($\mathbf{I}^+$ and $\mathbf{I}^-$) and distance of alternatives from these solutions and relative closeness to positive ideal solutions are calculated for each criterion.

Step 7: Ranking of Alternatives:
The alternative with the maximum relative closeness is determined as the best alternative and the other alternatives are ranked according to their closeness to the ideal solutions (Liang 1999).

The algorithm uses an optimistic index to model the DM's risk attitude. We expect this will refer to some changes in the optimality, and consequently in the ranking of alternatives in applications as well.

2.2.2. The outranking method

The appealing point of the method proposed by Aouam *et al.* (2003) is that it allows attributes to be crisp or fuzzy, and provides a more flexible way of comparing alternatives. In addition, all fuzzy numbers used in this method are triangular fuzzy numbers which simplifies computations. In this section the method will be outlined. Its details can be found in (Aouam *et al.* 2003).

The fuzzy outranking function is based on 2 parts: the concordance and the discordance. The concordance part evaluates the outranking of alternative (a_i) with respect to another alternative (a_j) using threshold values s_j, ($j = 1, 2, \ldots, n$) for each criteria, where n denotes the number of criteria. The threshold s_j value for each criterion is used in comparing two alternatives. It represents a value beyond which the decision-makers have no doubt for preferring one alternative over the other. This method also considers the negative effect of comparing alternative (a_i) over alternative (a_j). In the calculations of the discordance part the fuzzy veto values play an important role. The fuzzy veto $\tilde{v}_j$ value for criteria j represents a threshold that beyond which one alternative cannot outrank the other alternative in any case. In this algorithm, the threshold values are crisp numbers, whereas the veto values are triangular fuzzy number. Note that the decision-maker controls the effect of the discordance part on the overall decision process via a parameter $\beta \in [0,1]$. A β value closer to one means that the discordance part is more important for the decision-maker.

Step 1: Determination of Parameters:
Firstly the weights (w_j) for each criteria and the weight (β) for the discordance part must be determined by the decision-maker. The DM also has to specify the maximum non-significant threshold values, s_j, and the fuzzy veto threshold values, $\tilde{v}_j$.
Step 2: Evaluation of Alternatives:
Each alternative with respect to each criterion is evaluated.
Step 3: Computation of the Concordance and Discordance Numbers:
Using fuzzy concordance and fuzzy discordance numbers alternatives will be ranked.
Step 4: Computation of the Overall Outranking Intensity Index
Step 5: Finding the Best Alternative (Aouam *et al.* 2003).

3. Application

In this section we shortly introduce the problems considered for application of the developed software. Each problem represents a typical class of important applications of FMCDM problems in real life situations.

3.1. Military staff assignment

Military staff is assigned to geographical regions rotationally in Turkey. There exist 7 main regions and each region consists of city centres. It is an important assignment problem for staff to be assigned to a preferred city centre, which is assumed to be the optimal alternative for him. Staff has an opportunity to list his preferences among the pre-determined city centres (Köse 2003).

Köse (2003) considered the assignment of military staff to various regions in Turkey. There are 9 criteria, 5 of which are objective and 4 are subjective. The objective criteria are C_2: social activities and entertainment; C_4: education opportunities; C_5: health conditions; C_6: level of welfare; C_7: local and suburban transport. The subjective criteria are: C_1: daily life; C_3: housing facilities; C_8: security and climate; C_9: payroll variance. There are 4 experts (DM_1, DM_2, DM_3, DM_4) determining the criteria weights. The final trapezoidal fuzzy weights for the criteria are determined by the DMs:

$\tilde{w}_1$ = <0.358 , 0.460 , 0.762 , 0.914> C_1: daily life (subjective)
$\tilde{w}_2$ = <0.330 , 0.439 , 0.740 , 0.900> C_2: social activities and entertainment (objective)
$\tilde{w}_3$ = <0.310 , 0.413 , 0.713 , 0.865> C_3: housing facilities (subjective)
$\tilde{w}_4$ = <0.290 , 0.392 , 0.692 , 0.844> C_4: education opportunities (objective)
$\tilde{w}_5$ = <0.250 , 0.369 , 0.669 , 0.825> C_5: health conditions (objective)
$\tilde{w}_6$ = <0.310 , 0.411 , 0.713 , 0.864> C_6: level of welfare (objective)
$\tilde{w}_7$ = <0.290 , 0.410 , 0.790 , 0.970> C_7: local and suburban transport (objective)
$\tilde{w}_8$ = <0.290 , 0.401 , 0.709 , 0.860> C_8: security and climate (subjective)
$\tilde{w}_9$ = <0.290 , 0.395 , 0.695 , 0.850> C_9: payroll variance (subjective)

3.2. Sniper gun selection

Weapon ranking systems use MCDM in performance evaluation, where the overall system characterization uses dependent or interactive criteria. In such systems, it is more appropriate to make the evaluations by conventional techniques like fuzzy systems. In the sniper gun selection problem, considered by Bozkaya (2004), 4 alternatives are evaluated by 6 criteria. The alternatives considered are a_1: Druganov (Russia); a_2: SR25 (USA); a_3: Accuracy L96A1 (England); a_4: Steyr SSG-69 (Austria). The criteria weights are determined by the DMs as follows:

$w_1 = 0.3$ C_1: minute of angle (MOA)
$w_2 = 0.1$ C_2: weight of sniper gun (Weight)
$w_3 = 0.2$ C_3: effective range (Range)
$w_4 = 0.2$ C_4: binocular equipment (Binocular)
$w_5 = 0.1$ C_5: ergonomy
$w_6 = 0.1$ C_6: upgradeability

Notice that the criteria weights in the algorithm of Aouam *et al.* (2003) are defined as crisp numbers whereas in the algorithm of Liang (1999) they are defined as fuzzy numbers. The performance values of each alternative with respect to the criteria are given in Table 1.

Table 1. Sniper guns and criteria with threshold and fuzzy veto values

	MOA	**Weight (kg)**	**Range (m)**	**Binocular**	**Ergonomy**	**Upgradeability**
Dragunov	2.00	4.3	650	4×6 / PSO-1	Low	Medium
SR25	0.75	4.9	800	3.5-10×42	Very High	Very High
Acc. L96A1	0.50	6.8	800	3-12×42	High	Very High
Steyr SSG-69	0.50	4.6	800	6×Telescopik	Low	Medium
Threshold	0.2	0.2	0.2	0.2	0.2	0.2
Veto	<0.4,0.5,0.6>	<0.4,0.5,0.6>	<0.4,0.5,0.6>	<0.4,0.5,0.6>	<0.4,0.5,0.6>	<0.4,0.5,0.6>

The linguistic values for the binocular, ergonomy and upgradeability criteria are converted to triangular fuzzy numbers according to Table 2.

Table 2. Fuzzy numbers for linguistic values

Very high	<0.8, 1.0, 1.0>
High	<0.6, 0.8, 1.0>
Average	<0.3, 0.5, 0.7>
Low	<0.0, 0.2, 0.4>
Very Low	<0.0, 0.0, 0.2>

4. The software

As pointed out earlier, application of FMCDM methods may require considerable calculations. In addition it is important for DMs to take into account different risk attitudes and scenarios. Thus appropriate software is essential for adequate and timely results. The developed software provides a tool for the needed calculations and sensitivity analysis. It is developed by the Java programming language. Fig. 2 shows the basic interface of the program.

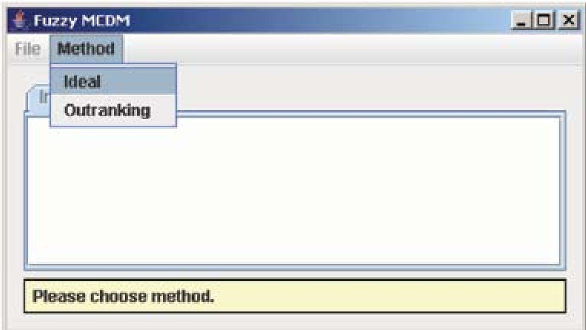


Fig. 2. Interface of the software

In this software version it is assumed that users provide the input for the problem by preparing a text file with a special structure for each method. For example, for the outranking method the file should start with the names of the criteria in one line, followed by each alternative evaluation in next lines, and finally the parameters of the method (Fig. 3).

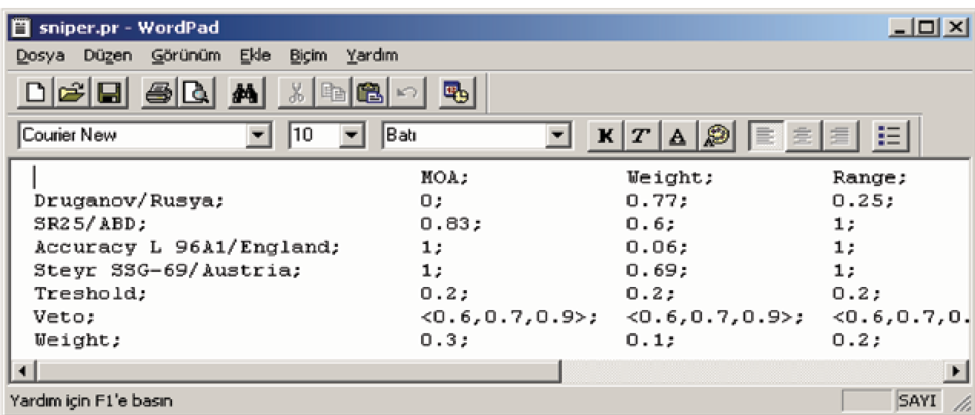
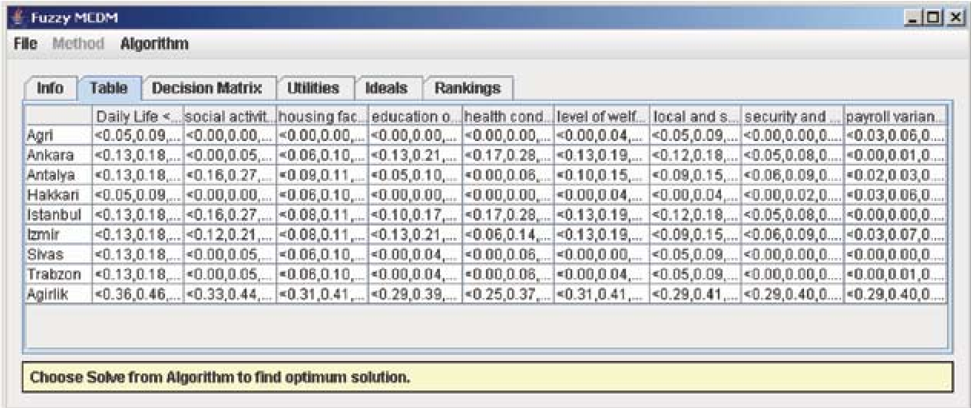


Fig. 3. Input file example for outranking method

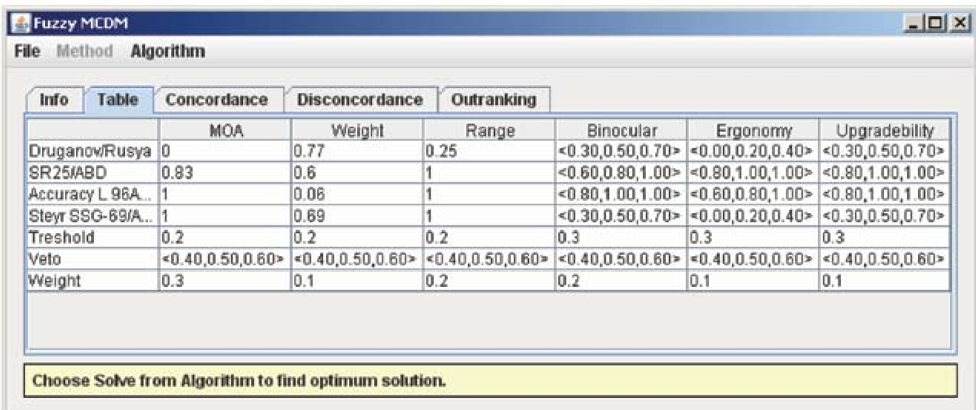
Fig. 4 shows an example FMCDM problem that has been loaded into the program. This example is the problem considered for applying the ideal points algorithm.

Fig. 5 shows an example of FMCDM problem considered for applying the outranking method. As is seen in Fig. 4 and 5, the program also provides information on intermediate calculations for each method.



	Daily Life <...	social activit...	housing fac...	education o...	health cond...	level of welf...	local and s...	security and ...	payroll varian...
Agri	<0.05,0.09,...	<0.00,0.00,...	<0.00,0.00,...	<0.00,0.00,...	<0.00,0.00,...	<0.00,0.04,...	<0.05,0.09,...	<0.00,0.00,0...	<0.03,0.06,0...
Ankara	<0.13,0.18,...	<0.00,0.05,...	<0.06,0.10,...	<0.13,0.21,...	<0.17,0.28,...	<0.13,0.19,...	<0.12,0.18,...	<0.05,0.08,0...	<0.00,0.01,0...
Antalya	<0.13,0.18,...	<0.16,0.27,...	<0.09,0.11,...	<0.05,0.10,...	<0.00,0.06,...	<0.10,0.15,...	<0.09,0.15,...	<0.06,0.09,0...	<0.02,0.03,0...
Hakkari	<0.05,0.09,...	<0.00,0.00,...	<0.06,0.10,...	<0.00,0.00,...	<0.00,0.00,...	<0.00,0.04,...	<0.00,0.04,...	<0.00,0.02,0...	<0.03,0.06,0...
Istanbul	<0.13,0.18,...	<0.16,0.27,...	<0.08,0.11,...	<0.10,0.17,...	<0.17,0.28,...	<0.13,0.19,...	<0.12,0.18,...	<0.05,0.08,0...	<0.00,0.00,0...
Izmir	<0.13,0.18,...	<0.12,0.21,...	<0.08,0.11,...	<0.13,0.21,...	<0.06,0.14,...	<0.13,0.19,...	<0.09,0.15,...	<0.06,0.09,0...	<0.03,0.07,0...
Sivas	<0.13,0.18,...	<0.00,0.05,...	<0.06,0.10,...	<0.00,0.04,...	<0.00,0.06,...	<0.00,0.00,...	<0.05,0.09,...	<0.00,0.00,0...	<0.00,0.00,0...
Trabzon	<0.13,0.18,...	<0.00,0.05,...	<0.06,0.10,...	<0.00,0.04,...	<0.00,0.06,...	<0.00,0.04,...	<0.05,0.09,...	<0.00,0.00,0...	<0.00,0.01,0...
Agirlik	<0.36,0.46,...	<0.33,0.44,...	<0.31,0.41,...	<0.29,0.39,...	<0.25,0.37,...	<0.31,0.41,...	<0.29,0.41,...	<0.29,0.40,0...	<0.29,0.40,0...

Fig. 4. Ideal-based method applied to the military staff assignment problem



	MOA	Weight	Range	Binocular	Ergonomy	Upgradebility
Druganov/Rusya	0	0.77	0.25	<0.30,0.50,0.70>	<0.00,0.20,0.40>	<0.30,0.50,0.70>
SR25/ABD	0.83	0.6	1	<0.60,0.80,1.00>	<0.80,1.00,1.00>	<0.80,1.00,1.00>
Accuracy L 96A...	1	0.06	1	<0.80,1.00,1.00>	<0.60,0.80,1.00>	<0.80,1.00,1.00>
Steyr SSG-69/A...	1	0.69	1	<0.30,0.50,0.70>	<0.00,0.20,0.40>	<0.30,0.50,0.70>
Treshold	0.2	0.2	0.2	0.3	0.3	0.3
Veto	<0.40,0.50,0.60>	<0.40,0.50,0.60>	<0.40,0.50,0.60>	<0.40,0.50,0.60>	<0.40,0.50,0.60>	<0.40,0.50,0.60>
Weight	0.3	0.1	0.2	0.2	0.1	0.1

Fig. 5. Outranking-based method applied to the sniper gun selection problem

5. Results and discussion

Military analyses carried out in peacetime are heavy users of probability theory, since many things about warfare are unknown or unknowable in the absence of the thing itself. The goals of warfare are multiple, so military analysts are often found groping for the right measure of effectiveness (Washburn 1994). From this point of view, multiple objectives in this study are designed in fuzzy environment. Addition to the complexity of military operations, fuzzy methodology brings new difficulties, which are thought to be eliminated by the proposed software.

The software application shows some interesting findings. In this section the results obtained are described and the findings discussed.

Fig. 6 shows the result of the ideal points method applied to the staff assignment problem with a 0.5 optimistic index value.

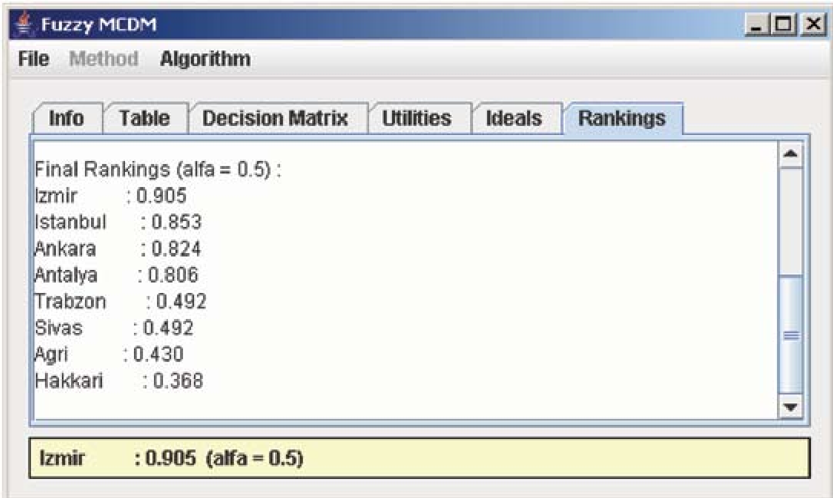


Fig. 6. Result of the staff assignment problem

Although fuzzy decision theory refers to some changes in optimal solutions or rankings due to the optimistic indices, we can not conclude this for the staff assignment problem. It was observed that the ranking of the optimal solution did not change for different values of the optimistic index. On the other hand, a careful analysis showed that for different values of the optimistic index some calculated values in the algorithm changed but the rankings remained the same.

Since the optimal ranking of the alternatives did not change due to the optimistic index, a detailed analysis was performed. This analysis showed that, when considering the criteria individually, for various optimistic indices, some criteria do not have unique optimal solutions. For instance, concerning the first criterion (C_1), the positive ideal solution is a_2, where a_3, a_5, a_6 and a_7 have the same distance from an ideal solution for C_1. However, the algorithm refers to only one alternative as optimal. The same situation is observed in C_2, C_4, C_5, C_6, C_7, C_8 (Table 3).

Because a_6 achieves optimality for 5 criteria (C_1, C_4, C_6, C_8, C_9), the optimal solution for the assignment problem is a_6. In the overall evaluation, the second best solution is a_5, which achieves optimality for criteria C_1, C_2, C_5, C_6 and C_7. In the optimal ranking, a_2 takes the third place, which achieves optimality for criteria C_1, C_4, C_5, C_6, and C_7. Considering the first 3 ranked alternatives (a_6, a_5, a_2), they all are best alternatives with respect to criteria C_1 and C_6. This indicates that for the first rank, C_4, C_8 and C_9 are more determinant/dominant than the others. Because the weights of these criteria are higher than the others, when an alterna-

Table 3. Positive ideal solutions

Criteria	I^+ alternatives in the first order	The other I^+ alternatives
C_1	a_2	a_3, a_6, a_6, a_7
C_2	a_3	a_5
C_3	a_3	-
C_4	a_2	a_6
C_5	a_2	a_5
C_6	a_2	a_5, a_6
C_7	a_2	a_5
C_8	a_3	a_6
C_9	a_6	-

tive gets a high score in that criterion, its overall score highly increases. In order to test this, we changed the weights and run the software for the assignment problem. We decreased the weights for C_4, C_8 and C_9, which have the most important effects in the problem. The new weight values are presented in Fig. 7. According to the result of this decrease, the ranking changed, as given in Fig. 8. It shows that these weights have an important effect in achieving the optimal decision.

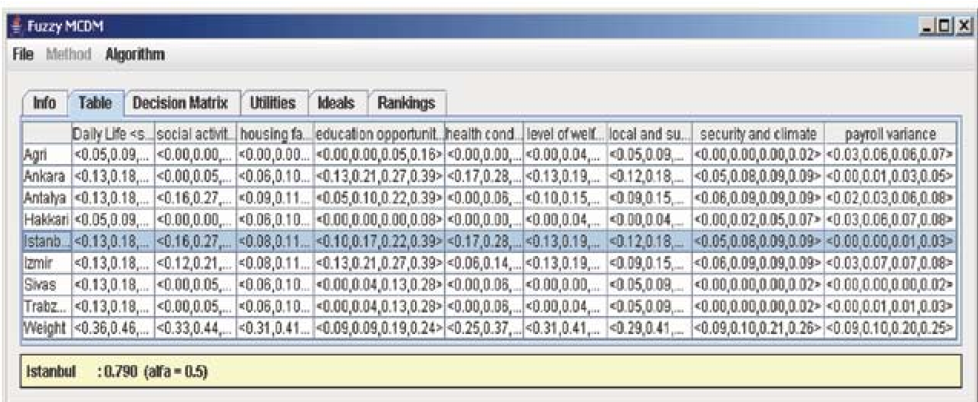


Fig. 7. Reduced weights for C_4, C_8 and C_9

Fig. 9 shows the result of the outranking method applied to the sniper gun selection problem with $\beta = 0.5$. The best alternative is a_2: Accuracy L96A1 with an overall outranking intensity value of 0.976.

To see the effect of changing β, which represents the importance given to the discordance part, we have changed the values of β, as shown in Table 4.

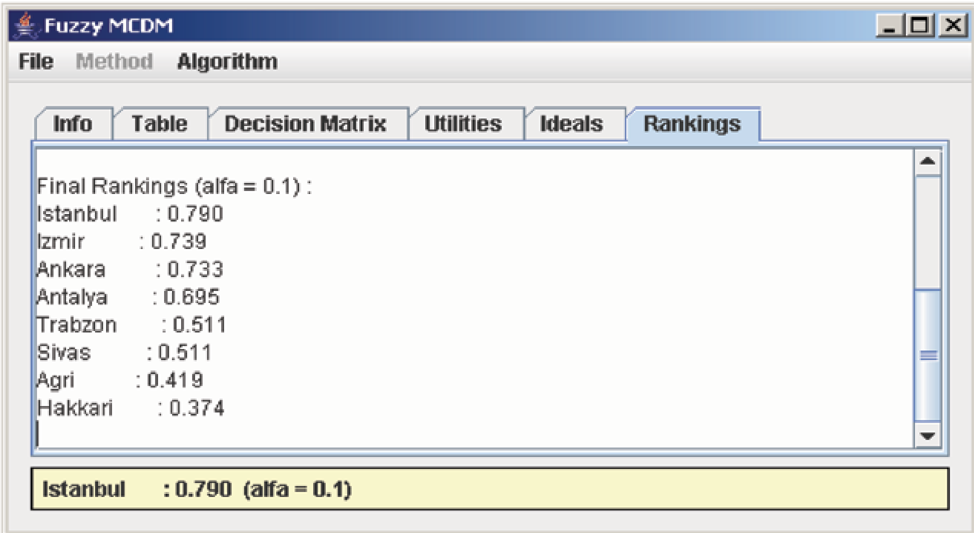


Fig. 8. Effects of reduced weights for C_4, C_8 and C_9

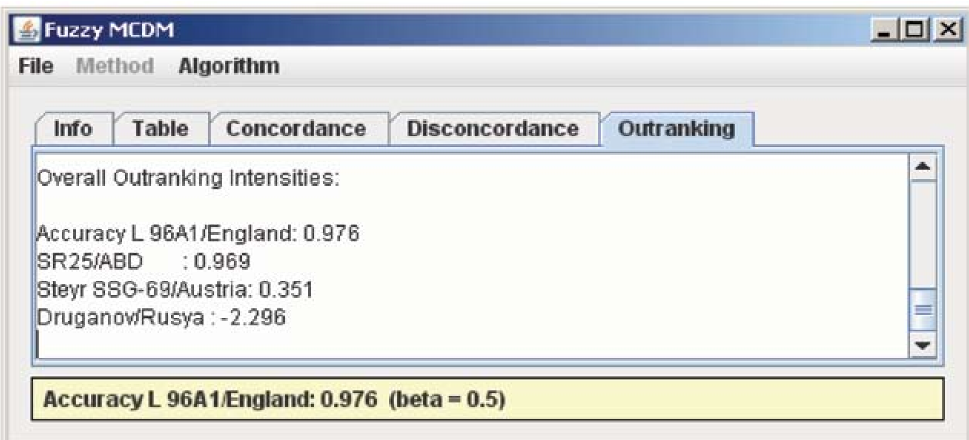


Fig. 9. Result of the sniper gun selection problem

Table 4. The effect of changing β on overall outranking intensities

					β						
$\tilde{v}_j$ = <0.4, 0.5, 0.6>	**0.0**	**0.1**	**0.2**	**0.3**	**0.4**	**0.5**	**0.6**	**0.7**	**0.8**	**0.9**	**1.0**
a_1: Druganov	–3.28	–3.08	–2.88	–2.69	–2.49	–2.30	–2.10	–1.90	–1.71	–1.51	–41.32
a_2: SR25	1.32	1.25	1.18	1.11	1.04	0.97	**0.90**	**0.83**	**0.76**	**0.69**	**0.62**
a_3: Accuracy L96A1	**1.49**	**1.38**	**1.28**	**1.18**	**1.08**	**0.98**	0.87	0.77	0.67	0.57	0.47
a_4: Steyr SSG	0.47	0.45	0.42	0.40	0.38	0.35	0.33	0.30	0.28	0.26	0.23
Best alternative	a_3	a_3	a_3	a_3	a_3	a_3	a_3	a_3	a_2	a_2	a_2

Note that, while changing β, the threshold values are held constant. As Fig. 10 clearly shows, increasing the value of β decreases the overall outranking intensity value for alternative a_3 (Accuracy L96A1) quite rapidly. Though at the same time, the overall outranking intensity value for alternative a_2: SR25 also decreases, the rate of decrease is not as fast as for alternative a_2. The reason, why alternative a_3 decreases more rapidly with respect to β, can be seen in Fig. 5. Note that in this figure, the "weight" criterion for alternative a_3 has the worst performance value (0.06), which is much lower than for all other alternatives. Hence increasing the importance of the discordance part has an impacting effect on the preference for alternative a_3. We have not included a_1 (Druganov) in the graph because, as can be seen from Table 4, all outranking intensities are negative for this alternative.

A similar analysis regarding the veto threshold values may also be investigated. We note that, without giving any details, it can be seen that increasing the veto thresholds has the effect of reducing the discordance part. This may be explained by noting that an increased veto threshold means actually that a veto effect is more difficult to observe.

6. Conclusions

The main aim of this study was to develop software which can be expanded to some other FMCDM algorithms. The developed software enables calculations practically and allows observing effects of attitude of DMs on the optimal decision.

For various optimistic indexes, the software was run and the optimal solutions were calculated. We note that for the Ideal and Anti-Ideal Concept algorithm, although the calculated values were different, these differences did not lead to any changes in the rankings.

Changing parameters in the outranking-based method led to a different ranking of the alternatives. It was also possible to see the effect of the veto and threshold parameters in

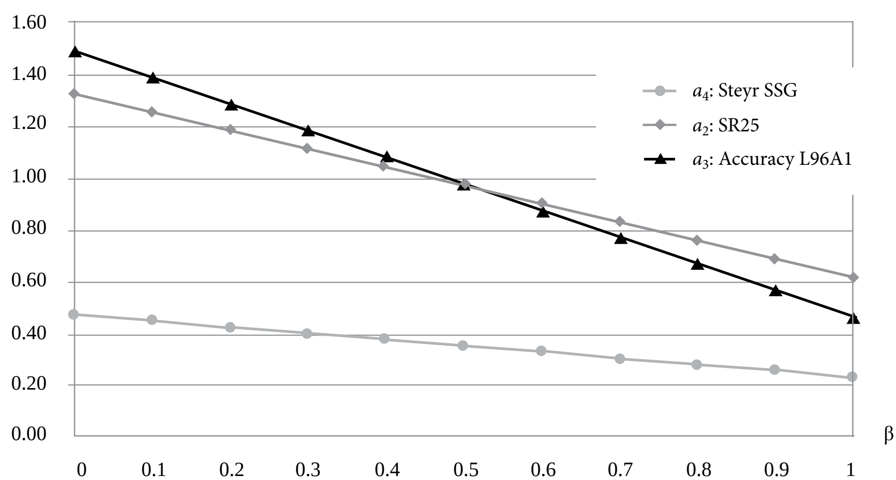


Fig. 10. Effect of changing β ($\tilde{v}_j$ constant)

this method. In addition, it was possible to see how a criterion may affect the ranking of an alternative, when it has an exceptionally bad performance with respect to this criterion. On the other hand, we did not observe any changes in the ranking of the Ideal and Anti-Ideal Concept algorithm. Hence a detailed analysis was conducted on the results of the Ideal and Anti-Ideal Concept algorithm. This analysis showed that, when considering the criteria individually, for various optimistic indexes, some criteria do actually not have unique positive ideal solutions.

This study also points out some handicaps encountered in applications of FMCDM problems, as it usually requires considerable calculations and determination of some critical parameter values. The results of the real applications and previous studies in the literature show that these methods can be further improved. For example, one may consider inferring the veto-related parameters from outranking examples, as shown in Dias and Mousseau (2006). Moreover, the fact that for some optimistic indexes, some criteria have more than one positive ideal solution should be further investigated.

The proposed software is a starting point for overcoming some of these difficulties for the introduced methods. The software can be improved in some respects, such as being more user-friendly and having graphs for sensitivity analysis. In addition to enabling the complex calculations needed, the software also presents steps of these algorithms in details.

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PROGRAMINĖS ĮRANGOS KŪRIMAS NEAPIBRĖŽTŲJŲ AIBIŲ DAUGIAKRITERINIAM SPRENDIMŲ PRIĖMIMUI

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Santrauka

Aprašomos programos, skirtos daugiakriteriniam sprendimų priėmimui esant neapibrėžtumams, kūrimas ir jos pritaikymas sprendžiant dvi realias problemas. Neapibrėžtųjų aibių daugiakriteriniai metodai plačiai taikomi, kai esama netikslių duomenų arba lingvistinių kintamųjų. Taikant šiuos metodus galima lengviau išspręsti sprendimo priėmimo problemas, sudaryti tikslesnius modelius. Nors tokiu atveju reikia daugiau skaičiavimų siekiant taikyti neapibrėžtąsias aibes daugiakriteriniuose sprendimų priėmimo algoritmuose, tačiau galimybė įvertinti neapibrėžtumus suteikia pranašumų, palyginti su klasikiniais metodais. Taigi neapibrėžtųjų aibių daugiakriteriniams metodams labai svarbu tinkama programinė įranga. Svarbiausias

šio tyrimo tikslas – sukurti programinę įrangą ir testuoti ją sprendžiant dvi tikras karines problemas – idealiųjų taškų algoritmą ir rangavimų metodą. Rezultatai aptarti atlikus jautrumo analizę.

Reikšminiai žodžiai: neapibrėžtųjų aibių daugiakriterinis sprendimų priėmimas (NADSP), idealieji taškai, rangavimas, programinė įranga.

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