DE GRUYTER OPEN

STUDIES IN LOGIC, GRAMMAR AND RHETORIC 37 (50) 2014

DOI: 10.2478/slgr-2014-0025

The Multi-Criteria Negotiation Analysis Based on the Membership Function

Ewa Roszkowska[1], **Tomasz Wachowicz**[2]

[1] Faculty of Economics and Management, University of Bialystok, Poland, erosz@o2.pl
[2] Department of Operations Research, University of Economics in Katowice, Poland, tomasz.wachowicz@ue.katowice.pl

Abstract. In this paper we propose a multi-criteria model based on the fuzzy preferences approach which can be implemented in the prenegotiation phase to evaluate the negotiations packages. The applicability of some multi-criteria ranking methods were discussed for building a scoring function for negotiation packages. The first one is *Simple Additive Weighting* (SAW) technique which determines the sum of the partial satisfactions from each negotiation issue and aggregate them using the issue weights. The other one is Distance Based Methods (DBM), with its extension based on the distances to ideal or anti-ideal package, i.e. the TOPSIS procedure. In our approach the negotiator's preferences over the issues are represented by fuzzy membership functions and next a selected multi-criteria decision making method is adopted to determine the global rating of each package. The membership functions are used here as the equivalents of utility functions spread over the negotiation issues, which let us compare different type of data. One of the key advantages of the approach proposed is its usefulness for building a general *scoring function* in the ill-structured negotiation problem, namely the situation in which the problem itself as well as the negotiators preferences cannot be precisely defined, the available information is uncertain, subjective and vague. Secondly, all proposed variants of *scoring functions* produce consistent rankings, even though the new packages are added (or removed) and do not result in rank reversal.

Keywords: negotiation support, membership function, fuzzy multi-criteria methods

1. Introduction

Negotiation may be perceived as an iterative process of exchanging offers and messages between the contracting parties that is being conducted until the satisfying agreement is reached. In bilateral negotiation the agreement will be reached if it is satisfying for both parties, i.e. the negotiator and his counterpart (Thompson, 1998; Gimpel, 2007; Raiffa, 1982; Roszkowska 2011). In the prenegotiation phase the negotiator, among others, evaluates negotiation packages to determine which of them satisfies him/her the best, as well as to rank them in order (Wachowicz 2010). To do so he/she can use a *scoring function*, which takes into account negotiator's preferences with respect to all issues as well as their relative importance (applies a weighting mechanism). In practice negotiation packages are often characterized by several, usually conflicting issues. There may be no package which satisfies all the criteria simultaneously, so there is no one *ideal package* which is the best for all the issues. Therefore it seems quite important to evaluate each feasible negotiation package to be able to compare them and choose the most satisfying contract. Unfortunately such evaluation is often conducted while the preference information is uncertain, subjective and imprecise, so the problem is ill structured.

The Multiple Criteria Decision Analysis (MCDA) includes a large class of methods for the evaluation, ranking, sorting or selection of various alternatives described by different criteria, which can be also useful in negotiation process (Salo, Hamalainen 2010; Figueira et al., 2005; Brzostowski at el., 2012). Traditionally, a multiple criteria decision making (MCDM) technique takes the set of alternatives and the set of criteria as given, and focuses on preference elicitation and aggregation. But in the negotiation context it needs to be taken into account that during negotiation process negotiator can search for and construct new packages and evaluate them using the scoring function. The optimal *scoring function* should produce consistent ranking even though the new packages are added to (or removed from) the predefined negotiation template and should not result in rank reversal (García-Cascales, Lamata, 2012; Schenkerman 1994; Wang, Luo 2009). This means that in the case of adding or removing of a new package the negotiator does not need to re-evaluate the previously evaluated packages and the scores of all those packages remain stable.

To deal with those problems of preference imprecision, rank reversals and ill structure of the negotiation problem, we propose an approach based on the fuzzy multi-criteria analysis. The fuzzy membership function is used here to deal with fuzzy preferences and imprecise evaluation of packages.[1] Using membership function we transform the resolution levels of negotiation issues into a common normalized preference scale $\langle 0, 1\rangle$ – the values of which describe the negotiator's *degree of satisfaction* with negotiating a given option – which makes the between-issue comparisons of the option values possible. Additionally, since the importance of each issue is not equal, i.e. some issues may be more important than others, we assume that the issues need to have the weights assigned. The scoring function which is *a global satisfaction measure* can be determined then and used for evaluation of the offers and for ordering them. This scoring function takes into account not only the negotiator's preferences described by membership function, but also the issues relative importance using a weighting mechanism.

The paper is organized as follows. Section 2 introduces briefly the fuzzy set theory and the notion of a membership function. In section 3 we formalize the multi-criteria negotiation model and identify its elements that may be supported by means of the proposed approach. While the incomplete information and vagueness is taken into consideration, we modify some multi-criteria scoring methods to obtain the fuzzy versions of algorithms applicable to the fuzzy context of the ill-structured negotiation problem. The membership function is used here to express the negotiator's preferences. In Section 4 the framework for some fuzzy multi-criteria methods is presented and the modifications for creating scoring function are discussed. The modified SAW technique and modified Distance Based Methods (DBM) can be used to calculate the overall score of the package. In Section 5 we present an example, which is thoroughly described to illustrate the model in detail and the results it provides the negotiators with. Finally, we summarize the paper's major ideas in the conclusion sections.

2. Fuzzy sets and membership functions

The *Fuzzy Sets Theory* was introduced by Zadeh (1965) to deal with vague, imprecise and uncertain problems. The fuzzy set concepts provide us with tools that are useful for modeling complex systems despite the fact that it may be difficult to define them precisely. A fuzzy set is an extension of a crisp set. The crisp sets use the notions of a full membership or non-membership at all only, whereas the fuzzy sets allow a partial membership. Membership function μ_A in crisp set maps all members of universal set X to the set $\{0, 1\}$ (Kwang 2005, p. 7):

$$\mu_A : x \to \{0, 1\}. \tag{1}$$

In fuzzy sets, each element is mapped by a membership function to the range $\langle 0, 1\rangle$:

$$\mu_A : x \to \langle 0, 1\rangle. \tag{2}$$

The value of the membership function $\mu_A(x)$ assigned to element x reflects to what extent this element belongs to the set X. According to formula (1), when crisp sets are considered an element x may simply be either a part of the set X or not. In fuzzy sets, this element may also be regarded as being *possibly* a part of X. Thus we may conclude that the fuzzy sets are the '*vague boundary sets*', while the crisp sets have solid and precisely defined boundaries.

Dubois (2011) pointed out that in their pioneering paper Bellman and Zadeh (1970) *"makes three main points:*

1. *Membership functions can be viewed as a variant of utility functions or rescaled objective functions, and optimized as such.*
2. *Combining membership functions, especially using the minimum, can be one approach to criteria aggregation.*
3. *Multiple-stage decision-making problems based on the minimum aggregation connective can then be stated and solved by means of dynamic programming."*

What is more, in the literature we can find five different possible interpretations of the membership function from the viewpoint of likelihood, randomness, similarity, utility and measurement (Bilgiç, Turksen, 2000).

In our approach we use the notion of *degree of satisfaction* measured by the membership function. This will allow us to consider the situations in which the decision maker (negotiator) is not only either fully satisfied or unsatisfied at all from the offer submitted, but also satisfied in some *degree.* It means that we use the notion of membership function as a variant of utility function.

To construct a membership function the negotiator may use one of the following methods (Bilgiç, Turksen, 2000; Chameau, Santamarina, 1987; Sancho-Royo, Verdegay, 1999):

- *polling*: a voting-like system of scoring the resolution levels that requires asking a question about each option separately allowing the dichotomous answer: yes or no. For instance: "Do you agree that *price in option A* is very good (satisfying)? (Yes/No)". For more complex option (e.g. the qualitative description of the *conditions of returns* in contract negotiation) a list of questions for each element of this option may be constructed. The value of membership function for this option is directly obtained as the quotient of the number of positive answers and the total number of questions asked.
- *direct rating (point estimation)*: an approach that requires negotiator to select one point on the "reference" axis (using numerical or verbal scale) that best describes this element. The questions are, for instance: "How good are *return conditions* in this offer?" or "Classify the *return conditions* of this offer according to its *degree of satisfaction* (degree of goodness)". This method is a straightforward way to come up with a precise form of the membership function, moreover it derives directly from the assumption that fuzziness arises from a subjective vagueness

of opinions of the individuals. The negotiator can also use this technique to compare the evaluations of various options in the predefined membership function.

- *reverse rating*: an approach that requires identification of the value of the issue's resolution level that is good/satisfying at a given degree. For instance: "Identify the *price* which is good at the degree of 0.5". In this method the negotiator is given a membership degree (*degree of satisfaction*) and then is asked to identify the resolution level for which that degree corresponds to the fuzzy term in question. Note, that instead of numerical representation of the degrees of satisfaction the verbal descriptors can be used.
- *interval estimation* (*set valued statistics*): a system, in which the negotiator is asked to declare the *intervals* that describe the quality of the issue's options. This method is similar to point estimation, but here the negotiator is allowed to select a reasonable range of possible values (or interval on the reference axis) that corresponds best to the question asked. For instance the question can be formulated in the following way: "Declare an interval within which you estimate/think the *very good* (*very satisfactory*) *price* lies".
- *membership function exemplification*: this method is referred as a "continuous direct rating". For instance, the negotiator is asked to write the number(s) which is appropriate for the extreme evaluation from the rating scale (i.e. extremely satisfying and extremely unsatisfying). Then the precision of the scoring system is increased by defining some intermediate levels, such as "good", "bad", "average" *degree of satisfaction*. In the next stages of the analysis is continued and additional intermediate levels are added between "good" and "average", and "average and "bad", depending on the expected granularity of the evaluation system.
- *pairwise comparison*: a system that requires a series of comparisons of the pairs of negotiation options. For instance, the negotiator is asked: which option A or B, is *more satisfactory* (and by how much?). Then the dyadic evaluations are aggregated to obtain the full ranking and numerical evaluations of each option separately. Such an aggregation may be conducted, for instance, by means of AHP (Saaty 1980).

3. The formalization of the negotiation model

The following section describes the proposed negotiation model explaining the nature of the negotiator's preferences, and the process of calculation of the packages' ratings using the multiple criteria decision making methods. The analysis of the multiple criteria decision making problem consists of several stages (Hammond et al., 2002): (1) defining the right decision problem; (2) clarifying decision maker's objectives and addressing the system of the evaluation criteria; (3) developing a range of creative alternatives; understanding the consequences of these alternatives and evaluating them in terms of criteria; (4) making appropriate trade-offs among conflicting objectives (by applying a selected multiple criteria decision making method); and (5) building a ranking of alternatives and selecting the best solution. If the solution obtained is not accepted, e.g. for some behavioral biases, decision maker should gather new information and start the above process of problem solving again.[2] Similarly, a few steps are necessary to formalize the ill-structured negotiation model as a multi-criteria decision problem in fuzzy environment (Roszkowska et al., 2013).

Step 1. *Negotiation problem definition.*

Negotiator analyzes the problem that had appeared. He/she tries to recognize potential ways of solving it taking into account the goals and estimated preferences of both himself/herself and the potential counterpart in this problem.

Step 2. *Identification of the objectives and their transformation into the negotiation issues.*

Negotiator recognizes the major objectives connected with the negotiation and links them with all the criteria (issues) of the potential negotiation contract. The relevant negotiation issues are elaborated on the basis of these evaluation criteria. Let $Z = \{Z_1, Z_2, \ldots, Z_n\}$ denote the set of n negotiation issues.

Step 3. *Definition of negotiation space.*

Let D_i denote the negotiation issue dimension with respect to ith issue, which is bounded by the lowest acceptable target value (reservation limit) $r_i \in D$ and an aspiration value $a_i \in D_i$, where $i = 1, 2, \ldots, n$. These values define the maximum limit of demands as well as the minimum limit of concessions of the negotiator and constitute the negotiation space for each issue. Thus, each negotiation package (offer) can be represented in the form of a vector denoted by $P = [x_1, \ldots, x_n]$, where $x_i \in D_i$. Let us further denote by $P_I = [a_1, \ldots, a_n]$ the *ideal package*, and by $P_{AI} = [r_1, \ldots, r_n]$ the *anti-ideal package* in the considered negotiation problem.

Step 4. *Determination of the issue weights.*

The negotiator assigns a weight to each negotiation issue according to his/she subjective preferences that reflects the issue's relative importance.[3]

Let us denote the issue weight vector as $w = [w_1, \ldots, w_n]$, where $w_1 + \ldots + w_n = 1$, $w_i \in \Re^+$.

Step 5. *Elicitation of issue preferences and construction of fuzzy membership functions for each issue.*

The negotiation issues can be described by different types of data such as numerical, linguistic or mixed values. For instance, *the price* is numerical and the *return condition* is qualitative. To compare various resolution levels of the negotiation issues in terms of preferences we have to transform different types of values into a standard unit. This common unit is regarded as the negotiator's *satisfaction degree* and in this paper is represented by a fuzzy membership function (see Section 1). In this way all the preference values for each issue are scaled between 0 and 1 to have the same range of measurement.

Some preferences can be transformed in a continuous way, others need a discrete transformation. For instance, concepts like *price* and *profit* can be represented by a continuum of values, and the extent to which they are satisfied can be determined by a fuzzy membership function. The *continuous membership function* can be constructed from the given set of discrete points (evaluations) specified by the negotiator answering a *finite* number of questions but next, the approximation is required to cover with the rates the whole feasible evaluation space. The other preferences like *warranty* or *return conditions* require discrete modeling because they can only hold a finite number of resolution levels (e.g. have a qualitative nature). The discrete preferences can be represented by a fuzzy set of ordered pairs of value and satisfaction. In our approach we use the fuzzy continuous membership functions for the continuous data, and the discrete membership functions for the other types.

Let $s_i : D_i \to \langle 0, 1\rangle$ be a membership function with respect to ith issue, where $s_i(x) = \hat{x}_i \in \langle 0, 1\rangle$, for $x \in D_1$, The value $s_i(x)$ is a *satisfaction degree* with an option $x \in D_i$ of ith issue. Consequently, $s_i(r_i) = 0$ and $s_i(a_i) = 1$. Now every package P is represented by a vector $\hat{P} = [\hat{x}_1, \hat{x}_2, \ldots, \hat{x}_n]$, where $\hat{x}_j$ is a *satisfaction degree* of the option of $j$the issue in this package. The ideal package P_I is represented by a vector $\hat{P}_I = [1, 1, \ldots, 1]$ whereas anti-ideal package P_{AI} by the vector $\hat{P}_{AI} = [0.0. \ldots, 0]$. Note that the membership function plays here also a role of the normalization formula, that should be conducted extra in the classical MCDM techniques.

Step 6. *Evaluation of negotiation packages (using the multiple criteria decision making method for ranking/ordering the packages).*

To calculate the *global satisfaction* for the negotiation package we need to determine the formula of the scoring function. Such a function should take into account the negotiator preferences as well as their relative importance over the issues. Thus, the negotiator's decision problem can be formally described as the four-tuple: $(Z, M\ w, SF)$ where Z – is a set of issues, M – is the set of membership functions, w – the weights vector, SF – the scoring function.

Let us denote the set $S = \{SF(P_i) : P_i \in P\}$ of scoring values for finite set $P = \{P_1, \ldots, P_k\}$ of packages, where SF is a scoring function. The differences $\Delta SF_{i/k} = SF(P_i) - SF(P_k)$ can be interpreted as a cardinal measure of concessions made by the negotiator by changing the offer P_k to P_i.

Having performed the algorithm described above the negotiator obtains the full scoring system of the negotiation offers. Each feasible offer submitted by himself/herself or his/her counterpart may be compared to the ones sent before and regarded to be better or worse. Furthermore, the scale of concessions may be precisely determined, which helps to evaluate the negotiation dynamics and consider, if the satisfying compromise is possible to reach before the negotiation deadline. In the vocabulary of the negotiation analysis (Raiffa et al., 2002) first three stages of the algorithm described above are known as the negotiation template design, while the last three – the negotiation template evaluation.

4. Scoring functions

In this section we propose the scoring functions which can be useful to be applied in step 6 of the process of analyzing the ill-structured negotiation problem described in previous section. The classic scoring methods we suggest to apply were modified to be applicable in our fuzzy negotiation context.

The simplest technique that can be applied here is based on SAW procedure (Keeney, Raiffa, 1976) where the *global satisfaction* from the package P is calculated as a simple weighted average:

$$S(P) = S(x_1, \ldots, x_n) = \sum_{i=1}^{n} w_i s_i(x) = \sum_{i=1}^{n} w_i \hat{x}_i \qquad (3)$$

where $s_i(\bullet)$ is a *membership function* which measures *satisfaction* with respect to ith issue $i = 1, 2, \ldots, n$.

Note that

$$S(P_I) = 1 \ \text{ and } \ S(P_{AI}) = 0. \qquad (4)$$

The negotiator can also use other MCDM method to calculate global satisfaction from the package, for the SAW-based scoring systems may be in some situations misinterpreted or misused (Wachowicz, Kersten, 2009; Wachowicz, Wu, 2010). Here we discuss in detail the applicability of the Distance Based Methods (DBM). There are two fundamentally different versions of this method. In the first one the negotiator takes into account the *ideal package*, the components of which are based on aspiration levels of the different issues. The evaluation vector $\hat{P} = [\hat{x}_1, \hat{x}_2, \ldots, \hat{x}_n]$ of each package P is compared with the evaluation vector $\hat{P}_I = [1, 1, \ldots., 1]$ of ideal package P_I by computing the distance between these packages (see VIKOR (Opricovic, Tzeng, 2007)). In the second approach the negotiator takes into account the anti-ideal package P_{AI}, the components of which are based on reservation levels of the different issues. The evaluation vector $\hat{P} = [\hat{x}_1, \hat{x}_2, \ldots, \hat{x}_n]$ of each package P is compared with the evaluation vector $\hat{P}_{AI} = [0, 0, \ldots, 0]$ of anti-ideal package P_{AI} by computing the distance between them and taking into account the weight of each issue. The package P with the largest distance is then selected as the best choice.

In most applications the weighted Minkowski-distance is used, where $p > 1$ is a positive user-dependent model parameter. Then the distance of package P to the ideal package P_I is given by:

$$D^p(P) = D^p(P, P_I) = \left(\sum_{i=1}^{n} (w_i s_i(a_i) - w_i s_i(x))^p \right)^{\frac{1}{p}} = \\ = \left(\sum_{i=1}^{n} (w_i - w_i s_i(x))^p \right)^{\frac{1}{p}} \tag{5}$$

and the distance of package P to the anti-ideal package P_{AI} is given by:

$$d^p(P) = d^p(P, P_{AI}) = \left(\sum_{i=1}^{n} (w_i s_i(x) - w_i s_i(r_i))^p \right)^{\frac{1}{p}} = \\ = \left(\sum_{i=1}^{n} (w_i s_i(x))^p \right)^{\frac{1}{p}} \tag{6}$$

Let us note that

$$D^p(P_I) = 0, \quad D^p(P_{AI}) = \left(\sum_{i=1}^{n} (w_i)^p \right)^{\frac{1}{p}} \tag{7}$$

and

$$d^p(P_I) = \left(\sum_{i=1}^{n} (w_i)^p \right)^{\frac{1}{p}}, \quad d^p(P_{AI}) = 0. \tag{8}$$

Another version of distance based methods is Technique for Order Performance by Similarity to Ideal Solution known as the TOPSIS (Hwang, Yoon, 1981) which combines the distances D^p and d^p:

$$T^p(P) = \frac{d^p(P, P_{AI})}{d^p(P, P_{AI}) + D^p(P, P_I)} \tag{9}$$

where $0 \leq T^p(P) \leq 1$.

Note that

$$T^p(P_{AI}) = 0, \quad T^p(P_i) = 1. \tag{10}$$

The TOPSIS procedure developed by is based on the concept of the relative distance, which ascertain that the chosen package should have the shortest distance to the ideal package and the farthest distance to the anti-ideal package. The choice of a particular value of this compensation parameter p in formulas (5), (6) and (9) depends on the type of problem and the desired solution. Note that in the case of $p = 1$, some scoring functions are equivalent to each other and the following stays true:

$$S(P) = 1 - D^1(P) = d^1(P) = T^1(P). \tag{11}$$

The advantage of the scoring functions presented above is that they allow for an easy evaluation of any new package added to the scoring system after it was determined in the prenegotiation phase. In case the new package is added the negotiator does not need to re-evaluate the previously evaluated packages, in addition the ratings of all the packages that were evaluated before remain stable. What is more, the scoring function produces consistent ranking and does not result in rank reversal after adding or removing the packages to/from the evaluation set (García-Cascales, Lamata 2012; Schenkerman, 1994; Wang, Luo, 2009). The rank reversal situation is very common in the classic algorithms of such MCDM methods as AHP, TOPSIS, ELECTRE or PROMETHEE. When new alternatives are added they may cause the unexpected and irrational change of the ranking of the previously assessed packages (De Keyser, Peeters, 1996).

In the next section we will present an example illustrating how the mechanisms of the proposed approach may be implemented to negotiation support, in particular, to analyzing negotiator's preferences and building the scoring system for the negotiation offers.

5. Numerical example

5.1. Building the membership function for negotiator's preferences

Let us assume that two parties are negotiating the conditions of the potential business contract. The following three issues are discussed: *price* (Z_1), *time of payment* (Z_2) and *returns conditions* (Z_3). The negotiation spaces for Z_1, Z_2 are Z_3 the following:

- *Price* (EUR): between 15 and 30 EUR per unit (will be defined precisely in the negotiations);
- *Time of payment* (days/weeks): between the moment of the delivery and a three-week time (will be defined by means of the disjunctive intervals);
- *Returns*: defined qualitatively by four various options ⟨"5% defects and 4% penalty"; "5% defects and 2% penalty"; "3% defects and no penalty"; "7% defects and 4% penalty"⟩ the same for both parties.

Having such a negotiation template defined one of the ways for determining the membership function needs to be implemented to elicit the negotiators' preferences and generate the input data for the scoring system of the negotiation offers. Let us assume, that to identify the Seller's preferences for issue of *price* the mix of reverse rating (see Section 3) and the predefined linguistic scale is used. In defining this linguistic scale we used the classic context-free grammar approach with symmetrically distributed terms (see Herrera, Herrera-Viedma, 2000), with the result defuzzified for the calculation purposes. Such linguistic scale may differ depending on the granularity, even or odd ranges used for defining the terms etc. In our example the 7-point symmetric non-even linguistic scale is used (Table 1).

Table 1

7-point linguistic scale

Linguistics term (satisfaction)	Quantitative equivalent
Perfect (P)	1.00
Very high (VH)	0.80
High (H)	0.65
Medium (M)	0.50
Low (L)	0.35
Very low (VL)	0.20
None (N)	0.00

We start the simplified interactive procedure with a Seller. It consists of 3 questions that allow to identify three reference points within the feasible range of *price*:

- Question 1: "What is the *worst* option for issue of *price*?" ⟶ "Everything worse than 20 EUR is worth nothing to me",
- Question 2: "What is the *perfect* option for issue of *price* that would give you full satisfaction from the negotiation contract?" ⟶ "30 EUR would be perfect",
- Question 3: "What is a *medium resolution level* for you with regard to *price*?" – "An average 25 EUR".

We may represent now the issue of *price* through continuous membership functions in the following way:

$$s_p^S(x) = \begin{cases} 0 & \text{for } x \leq 20 \\ \dfrac{x-20}{10} & \text{for } x \in \langle 20, 30 \rangle \\ 1 & \text{for } x \geq 30 \end{cases} . \tag{12}$$

It can also be represented graphically (Fig. 1).

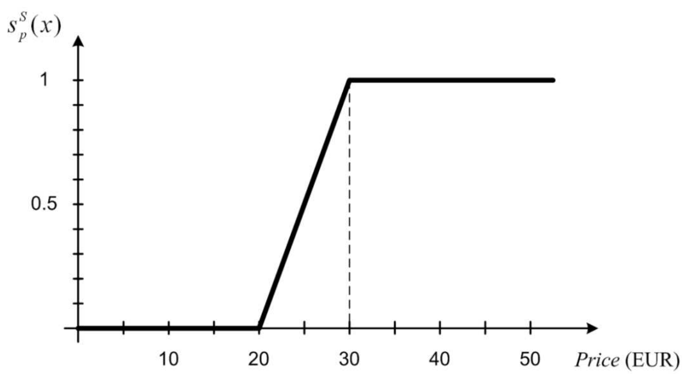

Figure 1. The Sellers membership function for *price*

Similar interaction with Buyer is required to determine his/her membership function for the issue of price. Let us assume, that according to the Buyer's responses we are able to identify membership function as represented in formula (13), shown in Figure 2.

$$s_p^B(x) = \begin{cases} 1 & \text{for } x \leq 15 \\ \dfrac{25-x}{10} & \text{for } x \in \langle 15, 25 \rangle \\ 0 & \text{for } x \geq 25 \end{cases} . \tag{13}$$

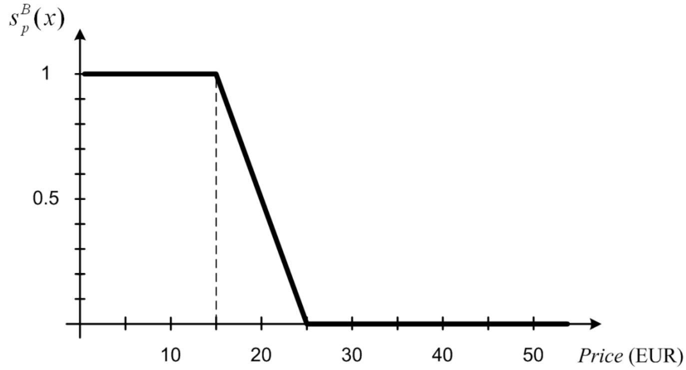

Figure 2. The Buyer's membership function for *price*

The membership functions reflecting the preferences of the negotiators over various resolution levels of the issue of *time of payment* are determined analogously. However, it may appear that sometimes the interval estimation, and even direct or indirect ratings are of better use. Let us assume, that the interaction with Buyer was the following:

- Question 1: "What is the *worst* option for *time of delivery*?" ⟶ "If I had to pay upon delivery or sooner than before business week I would be totally unsatisfied",
- Question 2: "What is the *perfect* option for *time of delivery*?" ⟶ "A month of grace period gives me full satisfaction".

Depending on the required granularity of the scoring system (e.g. a week-long basis) the following questions need to be asked more:

- Question 3: "How satisfied would you be if you had more than 7 days but no more than two weeks to pay an invoice?" – "I would be 20% satisfied".
- Question 4: "And between two and three weeks?" – "Well, it is fifty-fifty".
- Question 4: "And how high would your level of satisfaction be for payment between three and four weeks?" – "Very high".

Based on the above Buyer's responses the membership function may be constructed, which can be expressed by the following formula:

$$s_T^B(x) = \begin{cases} 0 & \text{for } x \le 7 \\ 0.2 & \text{for } x \in (7; 14\rangle \\ 0.5 & \text{for } x \in (14; 21\rangle \\ 0.8 & \text{for } x \in (21; 28\rangle \\ 0 & \text{for } x > 28 \end{cases}, \tag{14}$$

where x denotes the due date in days starting form the time of delivery.

Membership function (14) may be also presented graphically (Fig. 3).

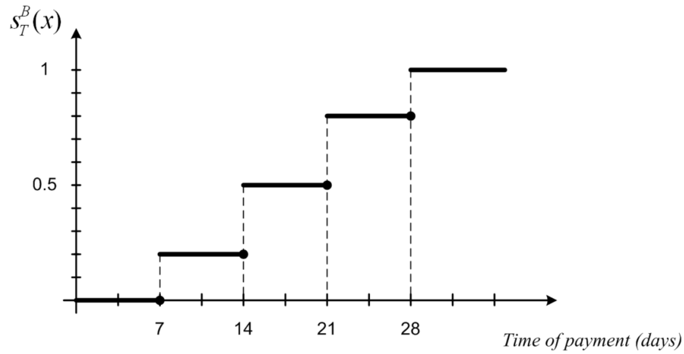

Figure 3. The Buyer's membership function for *time of payment*

Let us further assume, that the Seller's membership function was determined this very way and so we could obtain the following formula

$$s_T^S(x) = \begin{cases} 1 & \text{for } x \leq 7 \\ 0.7 & \text{for } x \in (7; 14\rangle \\ 0.6 & \text{for } x \in (14; 21\rangle \\ 0.2 & \text{for } x \in (21; 28\rangle \\ 1 & \text{for } x > 28 \end{cases}, \tag{15}$$

and its visualization (Fig. 4)

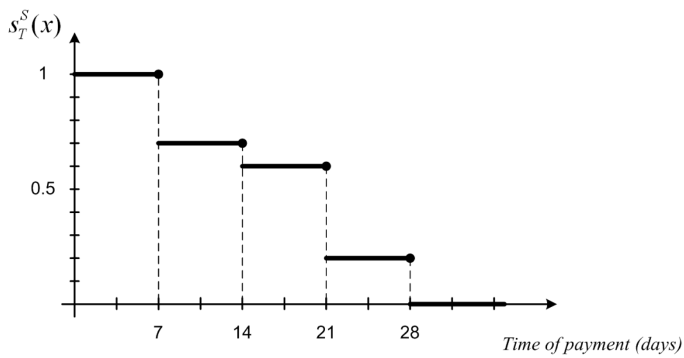

Figure 4. The Seller's membership function for *time of payment*

To elicit the discrete preferences over the options of the issue *returns*, the procedure of the direct rating needs to be applied. Let us assume that after dialoguing with the negotiators the fuzzy sets of ordered pairs (value, satisfaction) are determined:

- for Buyer: $Returns(B) = \{$("5% defects and 4% penalty", 0.5), ("5% defects and 2% penalty", 0.2), ("3% defects and no penalty", 0.7), ("7% defects and 4% penalty", 0.4)$\}$ (Fig. 5),
- for Seller $Returns(S) = \{$("5% defects and 4% penalty", 0.5), ("5% defects and 2% penalty", 0.6), ("3% defects and no penalty", 0.3), ("7% defects and 4% penalty", 0.4)$\}$ (Fig. 6).

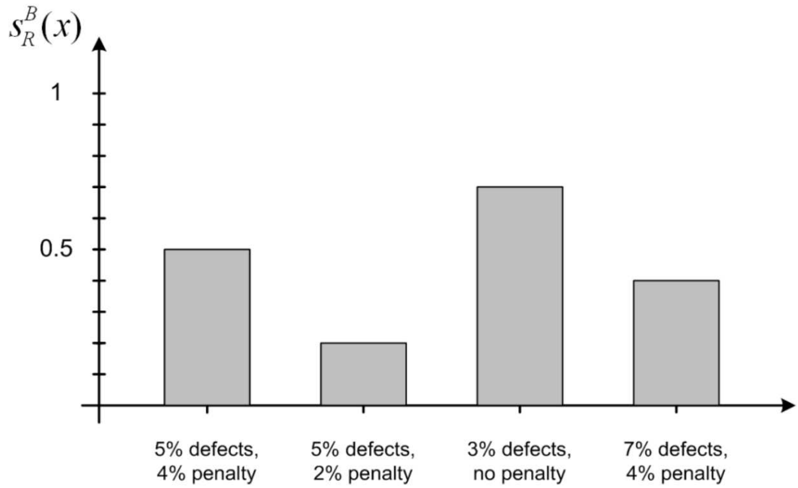

Figure 5. The Buyer's membership function for *returns*

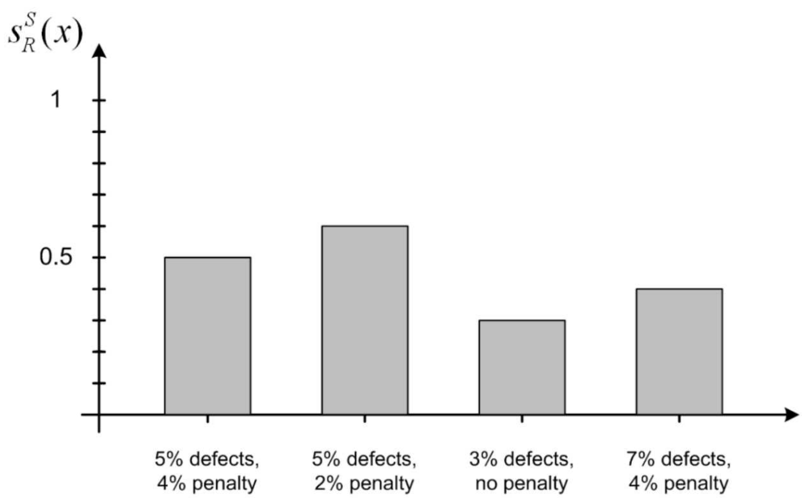

Figure 6. The Seller's membership function for *returns*

Let us suppose further that the vectors of the issues' weights are:

- $w_B = [0{,}7, 0{,}1, 0{,}2]$ for the Buyer
- $w_S = [0{,}8, 0{,}1, 0{,}1]$ for the Seller.

Having defined the preferences of the negotiators we may evaluate any feasible negotiation offer that consists of the options included in the feasible template (from different issues, from between aspiration and reservation levels).

5.2. Determining a scoring system of the negotiation offers

Suppose that during the prenegotiation phase the negotiators, discussing the feasible negotiation space and potential alternatives for negotiation contract, agreed for 15 feasible packages: $P_1, \ldots, P_{15}$ (see Table 2).

Table 2

Negotiation feasible packages

Package	Z_1 **Price** Buyer/Seller	Z_2 **Payment** Buyer/Seller	Z_3 **Return conditions** Buyer/Seller
P_1	20	between 8 and 14 days	5% defects, 4% penalty
P_2	20	between 15 and 21 days	3% defects, no penalty
P_3	20	between 22 and 28 days	7% defects, 4% penalty
P_4	21	between 8 and 14 days	5% defects, 2% penalty
P_5	21	between 15 and 21 days	5% defects, 4% penalty
P_6	21	between 15 and 21 days	7% defects, 4% penalty
P_7	23	between 8 and 14 days	3% defects, no penalty
P_8	23	between 22 and 28 days	3% defects, no penalty
P_9	23	between 22 and 28 days	7% defects, 4% penalty
P_{10}	24	between 15 and 21 days	5% defects, 4% penalty
P_{11}	24	between 22 and 28 days	3% defects, no penalty
P_{12}	24	between 22 and 28 days	7% defects, 4% penalty
P_{13}	25	between 8 and 14 days	5% defects, 4% penalty
P_{14}	25	between 22 and 28 days	3% defects, no penalty
P_{15}	25	between 22 and 28 days	7% defects, 4% penalty

The *global satisfaction measure* for each of these alternatives can be calculated using one of the formulas described in Section 4. We determined the Buyer's and Seller's scoring systems for the set of packages from Table 2 using the formulas: (4), (6), (7) and (9) with $p = 2$. The scoring systems of the negotiators are presented in Tables 3 and 4. The differences between scoring points obtained by different scoring functions are represented in Figures 7 and 8.

Table 3

Buyer's scoring systems

Package	Memberships function (Buyer)			Scoring function			
	Price	*Payment*	*Returns*	$S_B(P_i)$	$D_B^2(P_i)$	$d_B^2(P_i)$	$T_B^2(P_i)$
P_1	0,5	0,2	0,5	0,470 (2)	0,373 (2)	0,365 (2)	0,269 (2)
P_2	0,5	0,5	0,2	0,440 (3)	0,388 (3)	0,356 (3)	0,265 (3)
P_3	0,5	0,8	0,4	0,510 (1)	0,371 (1)	0,368 (1)	0,272 (1)
P_4	0,4	0,2	0,5	0,400 (6)	0,439 (5)	0,298 (5)	0,220 (5)
P_5	0,4	0,5	0,5	0,430 (4)	0,435 (4)	0,301 (4)	0,222 (4)
P_6	0,4	0,5	0,4	0,410 (5)	0,440 (6)	0,295 (6)	0,217 (6)
P_7	0,2	0,2	0,7	0,300 (8)	0,569 (8)	0,199 (8)	0,153 (8)
P_8	0,2	0,8	0,7	0,360 (7)	0,564 (7)	0,214 (7)	0,166 (7)
P_9	0,2	0,8	0,4	0,300 (8)	0,573 (9)	0,180 (9)	0,136 (10)
P_{10}	0,1	0,5	0,5	0,220 (11)	0,640 (11)	0,132 (13)	0,102 (13)
P_{11}	0,1	0,8	0,7	0,290 (9)	0,633 (10)	0,176 (10)	0,142 (11)
P_{12}	0,1	0,8	0,4	0,230 (10)	0,642 (12)	0,133 (12)	0,103 (12)
P_{13}	0	0,2	0,5	0,120 (13)	0,712 (15)	0,102 (15)	0,083 (15)
P_{14}	0	0,8	0,7	0,220 (11)	0,703 (13)	0,161 (11)	0,139 (9)
P_{15}	0	0,8	0,4	0,160 (12)	0,710 (14)	0,113 (14)	0,093 (14)

Table 4

Seller's scoring systems

Package	Memberships function (Seller)			Scoring function			
	Price	*Payment*	*Returns*	$S_S(P_i)$	$D_S^2(P_i)$	$d_S^2(P_i)$	$T_S^2(P_i)$
P_1	0	0,7	0,5	0,120 (13)	0,802 (13)	0,086 (12)	0,076 (12)
P_2	0	0,6	0,3	0,090 (14)	0,804 (14)	0,067 (13)	0,058 (13)
P_3	0	0,2	0,4	0,060 (15)	0,806 (15)	0,045 (14)	0,038 (14)
P_4	0,1	0,7	0,6	0,210 (10)	0,722 (10)	0,122 (9)	0,103 (9)
P_5	0,1	0,6	0,5	0,190 (11)	0,723 (11)	0,112 (10)	0,093 (10)
P_6	0,1	0,6	0,4	0,180 (12)	0,724 (12)	0,108 (11)	0,090 (11)
P_7	0,3	0,7	0,3	0,340 (7)	0,565 (7)	0,252 (6)	0,206 (6)
P_8	0,3	0,2	0,3	0,290 (9)	0,570 (9)	0,243 (8)	0,197 (8)
P_9	0,3	0,2	0,4	0,300 (8)	0,569 (8)	0,244 (7)	0,198 (7)
P_{10}	0,4	0,6	0,5	0,430 (4)	0,484 (4)	0,329 (3)	0,268 (3)
P_{11}	0,4	0,2	0,3	0,370 (6)	0,492 (6)	0,322 (5)	0,262 (5)
P_{12}	0,4	0,2	0,4	0,380 (5)	0,490 (5)	0,323 (4)	0,263 (4)
P_{13}	0,5	0,7	0,5	0,520 (1)	0,404 (1)	0,409 (1)	0,333 (1)
P_{14}	0,5	0,2	0,3	0,450 (3)	0,414 (3)	0,402 (2)	0,328 (2)
P_{15}	0,5	0,2	0,4	0,460 (2)	0,412 (2)	0,402 (2)	0,328 (2)

It should be noted here that different scoring functions may produce different ranking orders, which may lead to the selection of different packages as a potential negotiation compromise. However in this example all scoring systems for the Buyer as well as for the Seller result in similar rankings, but differ with respect to scoring points (see Table 3 and Table 4).

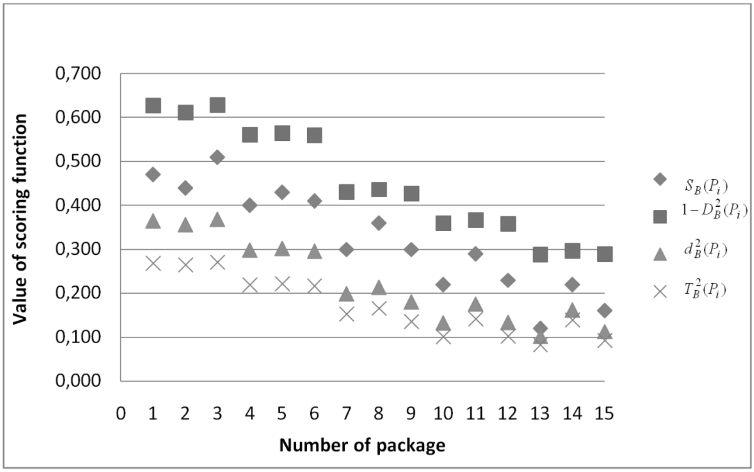

Figure 7. The scoring systems for the Buyer – an overview

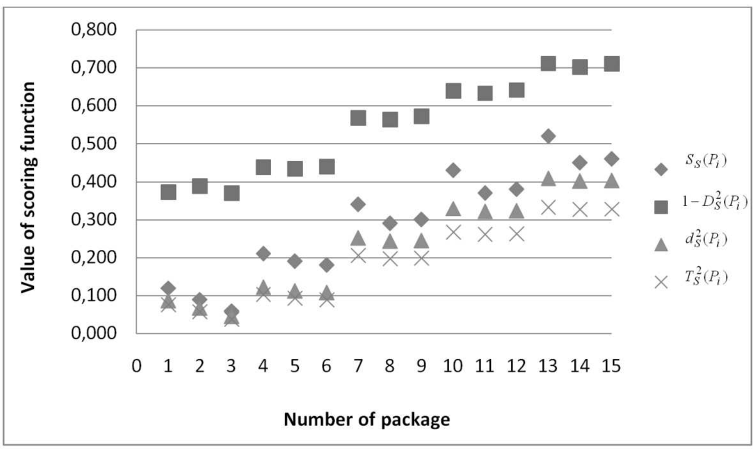

Figure 8. The scoring systems for the Seller – an overview

It must be taken into account by the negotiator that the differences between scoring points may have different interpretations depending on the global scoring formula they result from. Thus, the difference of 0.1 scoring points in TOPSIS-based scoring system cannot be compared with the difference of 0.1 scoring points in SAW-based one. Hence, if symmetric analysis is conducted no interpersonal comparisons of the scale of concession is allowed for different scoring systems used by the parties. Note also that all those scoring systems (and functions, in particular) for the Seller and Buyer can assess newly added package independently if needed.

In case the scoring systems for both sides are known the symmetrical analysis allows for identification of the possible negotiation solution as well as the Pareto-optimal packages. For illustration, let us assume that Buyer and Seller construct the scoring system using SAW procedure. The "*pair of satisfaction levels*" for the negotiators is described by $M_{(S,B)}$ in the following way:

$$M_{(S,B)}(P_i) = \{S_S(P_i); S_B(P_i)\},$$

where $i \in \{1, 2, \ldots, 15\}$.

Figure 9 represents the negotiation packages in the criteria space of the negotiators with respect to SAW scoring function.

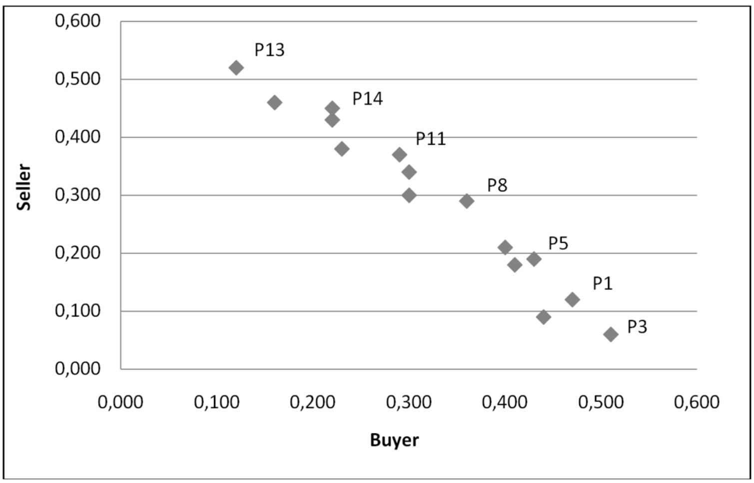

Figure 9. Negotiation packages in the criteria space of the negotiators – SAW procedure for both Seller and Buyer

The Pareto-optimal packeges are: P_1, P_3, P_5, P_8, P_{11}, P_{13} and P_{14} (see Figure 9). The recommended compromise ("fair") solutions could be P_8 or P_{10}, depending on the notion of fair solutions that can be applied in the negotiation symmetrical analysis (see Roszkowska et al., 2014).

6. Conclusions

In this paper we have presented and developed a fuzzy, multiple criteria model to be implemented in the negotiation process. Using the multiple criteria decision analysis a number of negotiation packages can be evaluated and compared with respect to several, usually conflicting issues. The aim of this analysis is to provide a support to the negotiator in the process of building scoring function. Such function can be used to identify a single preferred package or to rank packages; and to list a limited number of packages for subsequent submission in the consecutive negotiation round (building the concession strategy). We discussed mainly some application of MCDM methods based on membership function for building such scoring function, which we consider to be our major contribution to the theory of building and evaluation of the negotiation template and conducting the negotiation analysis. In this approach each issue is represented by a fuzzy membership function, which can be continuous or discrete, and has an assigned weight. Such fuzzy membership function evaluates the negotiator's degree of satisfaction for each issue options. To calculate the global satisfaction of a package we need to construct a scoring function where each issue's satisfaction is weighted based on the importance assigned to it by the negotiator. Therefore we presented several MCDM techniques that can be used to obtain such a measure of global satisfaction.

The concept of membership function is particularly useful for those negotiation problems in which the valuations of the packages on the basis of the criteria are expressed by subjective uncertain and vague judgments, where options are poorly defined and cannot be described with conventional quantitative terms. The most important advantages of proposed approach are the following:

1) Its usefulness for building *scoring function* in the ill-structured negotiation problem, i.e. situation when the problem itself as well as the negotiators preferences cannot be precisely defined, the available information is uncertain, subjective and imprecise.
2) The membership function as a measure of satisfaction from options takes a role of the normalization formula in MCDM methods, which let us not only compare the different type of data, but also evaluate the negotiation issues more precisely.
3) All proposed *scoring functions* based on membership function produces consistent ranking after new packages are added (or removed) and does not lead to rank reversal.

To verify the usefulness of the methodological approach proposed in this paper numerical example was presented were some multi-criteria methods were applied and obtained results were compared for creating scoring function in ill-structure negotiation problem.

Acknowledgements

This work was supported by the grant from Polish National Science Center DEC-2011/03/B/HS4/03857.

NOTES

[1] Note, that some other fuzzy approaches to solve this type of negotiation problems have also been proposed in literature (Roszkowska, Wachowicz 2012; 2013).

[2] The authors recommend also to recognize in detail the potential uncertainties, analyze risk-taking attitude and plan ahead for decisions linked over time. In this paper, however, we do not address the problem of negotiation context, the future relationship and the execution phase of the negotiation process, therefore we focus only on the five phases of problem solving process stated above.

[3] There are many approaches to determine the weights of issues. We can divide those approaches into subjective approaches and objective ones (see Brzostowski at el., 2012).

REFERENCES

Bellman, R.E., Zadeh, L.A. (1970). Decision making in a fuzzy environment. *Management. Science*. 17, 141–164.

Bilgiç, T., Turksen, I.B. (2000). Measurement of membership functions: Theoretical and empirical work, In. *Fundamentals of Fuzzy Sets. The Handbooks of Fuzzy Sets Series* 7, 195–227.

Brzostowski, J., Roszkowska, E., Wachowicz, T. (2012). Using Multiplie Criteria Decision Making Methods in Negotiation Support. *Optimum. Studia Ekonomiczne*, 5(59), 3–29.

Chameau, J.L, Santamarina, J.C. (1987). Measurement Membership Functions: Comparing Methods of Measurement. *International Journal of Approximate Reasoning*, 1, 287–301.

Chen, C.T. (2000). Extension of the TOPSIS for group decision-making under fuzzy environment. *Fuzzy Sets and Systems*, 114, 1–9.

De Keyser, W., Peeters, P. (1996). A note on the use of PROMETHEE multicriteria methods. *European Journal of Operational Research*, 89(3), 457–461.

Dubois, D. (2011). The role of fuzzy sets in decision sciences: Old techniques and new directions. *Fuzzy Sets and Systems*, 184, 3–28.

Figueira, J., Greco, S., Ehrgott, M. (2005). Multiplie Criteria Decision analysis: State of the Art Surveys. New York: Springer.

García-Cascales, S. M., Lamata M. T. (2012). On rank reversal and TOPSIS method. *Mathematical and Computer Modelling*, 56, 123–132.

Gimpel, H. (2007). *Preferences in Negotiations. The Attachement Effect.* Springer-Verlag: Berlin – Heidelberg.

Hammond, J.S., Keeney, R.L., Raiffa, H. (1998). Even Swaps: A Rational Method for Making Trade-offs. *Harvard Business Review*, 76(2), 137–149.

Hammond, J.S., Keeney, R.L., Raiffa, H. (2002). *Smart choices: A practical guide to making better decisions.* New York: Broadway Books.

Hwang, C. L., Yoon, K. (1981). *Multiple Attribute Decision Making: Methods and Applications.* Berlin: Springer-Verlag.

Keeney, R.L., Raiffa, H. (1976). *Decisions with multiple objectives: preferences and value trade-offs.* New York: Wiley.

Kwang H. Lee. (2005). *First Course on Fuzzy Theory and Applications.* Advances in Soft Computing. Berlin Heidelberg: Springer-Verlag.

Opricovic, S., Tzeng, G. H. (2007). Extended VIKOR method in comparison with outranking methods. *European Journal of Operational Research*, 178(2), 514–529.

Raiffa, H. (1982). *The Art and Science of Negotiation.* Cambridge (MA): The Belknap Press of Harvard University Press.

Raiffa, H., Richardson, J., Metcalfe, D. (2002). *Negotiation analysis: The science and art of collaborative decision making.* Cambridge (MA): The Balknap Press of Harvard University Press.

Roszkowska, E., (2011). Wybrane modele negocjacji, Białystok: Wydawnictwo UwB w Białymstoku.

Roszkowska, E., (2012). Zastosowanie metody TOPSIS do wspomagania procesu negocjacji, In: K. Jajuga, M. Walesiak, (Eds.) *Taksonomia 19. Klasyfikacja i analiza danych – teoria i zastosowania*, Wydawnictwo UE we Wrocławiu: Wrocław, 68–75.

Roszkowska, E., Wachowicz, T. (2012). Negotiation Support with Fuzzy TOPSIS. In: Teixeira de Almeida, A., Costa Morais, D., de Franca Dantas Daher, S. (Eds.). *Group Decision and Negotiations 2012. Proceedings.* Editoria Universitaria, Federal University of Pernambuco: Recife, 161–174.

Roszkowska, E., Brzostowski J., Wachowicz T., (2014). Negotiation Support in Ill-Structured Negotiation Problems, In: W. Pedrycz, P. Guo, (Eds.). *Human Centric Decision-Making Models for Social Sciences.* Springer Verlag, 339–367.

Salo, A., Hamalainen, R.P. (2010). Multicriteria Decision Analysis in Group Decision Processes. In: Kilgour, D.M., Eden, C. (Eds.), *Handbook of Group Decision and Negotiation.* Springer: New York, 269–283.

Saaty, T.L. (1980). *The Analytic Hierarchy Process*, New York, N.Y., McGraw Hill.

Sancho-Royo A., Verdegay. J.L., (1999). Methods for the Construction of Membership Functions. *International Journal of Intelligent Systems*, 14, 1213–1230.

Thompson, L. (1998). *The Mind and Heart of the Negotiator*. New Jersey: Prentice Hall, Upper Saddle River.

Schenkerman, S.. (1994). Avoiding rank reversal in AHP decision-support models. *European Journal of Operational Research* 74 407–419.

Wang, Y.M Luo, Y. (2009). On rank reversal in decision analysis. *Mathematical and Computer Modelling*, 49 (5–6), 1221–1229.

Wachowicz, T., Kersten, G.E. (2009). Zachowania i decyzje negocjacyjne uczestników negocjacji elektronicznych. In: K.A. Kłosiński, A. Biela (Eds) *Człowiek i jego decyzje. Tom 2*. Wydawnictwo KUL: Lublin, 63–74.

Wachowicz, T. (2010). Decision Support In Software Supported Negotiations. *Journal of Business Economics and Management*, 11(4), 576–597.

Wachowicz, T., Wu, S. (2010). Negotiators' Strategies and Their Concessions. In: de Vreede, G.J. (Ed.). *Group Decision and Negotiations 2010. Proceedings.* The Center for Collaboration Science, University of Nebraska at Omaha, 254–259.

Zadeh, L.A. (1965). Fuzzy sets. *Information and Control*, 8, 338–353.

Zadeh, L.A. (1975). The concept of a linguistic variable and its application to approximate reasoning: Part 1., *Information Sciences*, 8, 199–249.