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THE MACBETH APPROACH FOR EVALUATION OFFERS IN ILL–STRUCTURE NEGOTIATIONS PROBLEMS[2]

Summary

This paper described the main idea of the MACBETH approach and M-MACBETH software to multi-criteria negotiation analysis. The MACBETH is based on the additive value model and requires only qualitative judgments about differences of attractiveness to help a decision maker quantify the relative value of options or criteria. The main goal of this procedure is to support interactive learning about evaluation problems and to provide the recommendations to select and rankordering options/criteria in decision making processes.

We proposed to use MACBETH methodology as well M-MACBETH software to support ill-structure negotiation problems, i e. evaluation of negotiation offers in an environment with uncertain, subjective and imprecise information and not precisely defined decision makers preferences.

An numerical example showing how M-MACBETH software can be implemented in practice, in order to help a negotiator to define numerical values of options/criteria based on verbal statements and next build a scoring system negotiation offers taking into account different types of issues in negotiation problems is presented. More detail we describe the main key points of M-MACBETH software related to structuring the negotiation model, building value scales for evaluation negotiation packages, weighting negotiation issues and selected elements of sensitivity analyzes.

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Key words: MACBETH, M-MACBETH, qualitative judgments, support negotiation, preference analysis, scoring function

1. Introduction

The MACBETH (**M***easuring* **A***ttractiveness by a* ***C****ategory*-**B***ased* **E***valuation* **T***echnique*) is an interactive approach for multi-criteria value of the attractiveness or value of objects (options/criteria) through a non-numerical pairwise comparison questioning. The judgment is based on seven qualitative categories of difference in attractiveness: “no difference” (“indifference”), or is the difference “very weak”, “weak”, “moderate”, “strong”, “very strong”, or “extreme”. What is important and what differs MACBETH from other multi-criteria techniques, MACBETH uses only qualitative judgments of difference in attractiveness objects (options/weights) in order to generate, by mathematical

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programming, value scores for options and weights for criteria mode. The MACBETH procedure for generating the ranking of the options consists of the following main steps: structure the problem, followed by entering pairwise comparisons into a judgment matrix, calculating the attractiveness of options/criteria with sufficiently *consistent* matrix (otherwise the user is obliged to revise their judgments), construct value functions an optional make sensitivity and robustness analysis [Bana e Costa et al., 2003, 2005a, 2012; Bana e Costa, Vansnick, 1994, 1995, 1999].

The MACBETH approach and M-MACBETH software have been used to derive verbal preference judgment, construct value functions and scaling constants in various multi-criteria analysis, such as: evaluation of bids, public policy analysis, prioritization of projects, resources allocation and conflict management, credit scoring, strategic town planning, environmental management, portfolio management, airport management, risk management, firms competitiveness, resource allocation, among many others [Bana e Costa et al., 2005a]. Despite the MACBETH approach has already been considered in the literature with many applications there is no research on applying it to the support of the ill-structured negotiation problems.

In this paper we proposed to use MACBETH methodology as well M-MACBETH software in support negotiation. Negotiation is an iterative process of exchanging offers and messages between the interested parties that is conducted until the satisfying both parties agreement is reached [Thompson, 1998, Gimpel, 2007; Raiffa, 1982]. The important part of a negotiation analysis is a pre-negotiation phase where a negotiator evaluates offers, usually in form of negotiation packages, and rankordering them using a *scoring function*. Such function has to take into account the structure of negotiation problem, as well objective and subjective decision-makers' preferences. Multi-Criteria Decision-Making Methods (MCDM) offers a lot of techniques for the evaluation and ranking negotiation packages which can be used by the negotiator adequate to a negotiation situation as well negotiator's profile [see: Salo, Hamalainen, 2010; Figueira, et al, 2005; Brzostowski et al, 2012a, 2012b] Sometimes evaluation of negotiation packages takes place in an environment where the available information is uncertain, subjective and imprecise, packages are characterized by several qualitative as well quantitative issues, so the negotiation problem is ill structured.

In the paper a comprehensive MACBETH-based approach to support negotiation is presented, which is an original research contribution to the negotiation analysis. This contribution consists of the formulating the model of the decision problem in ill-structured negotiation, which allows the MACBETH approach to be applied to evaluate the negotiation template and M-MACBETH software to build MACBETH-based scoring system. Let us note, that other approaches to solve ill-structure negotiation problems have also been proposed in literature [Roszkowska, Wachowicz, 2012, 2014; Roszkowska et al, 2014; Wachowicz, Błaszczyk, 2012; Wachowicz et al, 2012].

The paper is structured as follows. Section 2 presents MACBETH methodology of questioning and technical procedure for elicitation value function as well M-MACBETH software. The negotiation model based on MACBETH approach is presented in Section 3. The example using M-MACBETH software is discussed in Section 4. Brief conclusions are drawn in Section 5.

2. The MACBETH Methodology

2.1. Mathematical foundation of MACBETH

The mathematical foundations of MACBETH are described in several papers [Bana e Costa et al., 2003, 2005a, 2012; Bana e Costa, Vansnick, 1994, 1995, 1999] and M-MACBETH software in [*M-MACBETH…,* 2005; Bana Costa 2005b]. The MACBETH approach has been developed since the early 1990s by Bana e Costa and Vansnick [2003]. Bana e Costa and Vansnick [1995] pointed out *"In Measurement Theory terminology, MACBETH is an interactive approach for mapping into a real scale various degrees of a property of the elements of a finite set A. The originality of MACBETH's questioning procedure is the possibility of establishing a constructive path towards cardinal measurement in both quantitative and substantive meaningful terms, avoiding the operational problems recognised as a weakness of other procedures. The use of the notion of semantic absolute judgments pays a key role here, and the simplicity, interactivity and constructiveness of our approach inserts it in the modern paradigms of decision aid'.*

Mathematically, MACBETH method is composed of few sequential PPLs (linear programming problems), which perform the analysis of cardinal consistency, the construction of the cardinal value scale which represents the set of judgments of the decision-maker, reveal sources of inconsistency, i.e. to check the existence of inconsistencies and suggest their solution. The exact formulation of these PPLs can be found in Bana e Costa and Vansnick [1995, 1999], Bana e Costa et al. [2012]. We present here the basic notion of *Measurement Theory* which are implemented in MACBETH procedure [for details see: Bana e Costa, Vansnick, 1995; Bana e Costa et al, 2012]. We define first two main types of scale: the ordinal scale and the cardinal scale.

Ordinal and cardinal value information. Let X be a finite set of elements or different options or performance levels under evaluation. *Ordinal measurement of the attractiveness* (or desirability) of the elements x of X consists in associating each $x \in X$ with a numerical score a real number v(x) that satisfies the following two ordinal measurement conditions [Bana e Costa, Vansnick, 1995; Bana e Costa et al., 2012]:

– **the condition of strict preference**

$$\forall x, y \in X \quad xPy \Leftrightarrow v(x) > v(y) \text{ (x is more attractive than y)} \tag{1}$$

– the condition of indifference

$$\forall x, y \in X \quad xIy \Leftrightarrow v(x) = v(y) \text{ (x is as attractive as y)} \tag{2}$$

A scale v that satisfies the measurement conditions (1)-(2) is an ordinal scale of measurement.

Cardinal measurement of the attractiveness of the elements x of X consists in associating each x with a numerical score -a real number $v(x)$ that satisfy conditions (1), (2) and also the following (3) condition [Bana e Costa and Vansnick 1995; Bana e Costa et al. 2012]: $\forall w, x, y, z \in X$ with x more attractive than y and w more attractive than z the ratio $\frac{v(x)-v(y)}{v(w)-v(z)}$ measures the difference in attractiveness between x and y when the difference in attractiveness between w and z is taken as the measurement unit. (3)

A scale v that satisfies the measurement conditions (1)-(3) is *interval scale* of measurement.

The numerical scale $v : X \to \Re;\ v \to v(x)$ can be constructed by positioning the elements of X on a vertical axis so that [Bana e Costa, Vansnick 1995; Bana e Costa et al., 2012]:

1. $\forall x, y \in X$: x is positioned above y if and only if x is more attractive than y (**ordinal value information**);
2. the relative distances between the elements of X on the vertical axis reflect the relative differences in attractiveness between these elements (**cardinal value information**).

The MACBETH judgment matrix. The MACBETH procedure transform *ordinal* information for *cardinal information* by a non-numerical *pairwise comparison* questioning mode in the form of MACBETH judgment matrix. On this judgment is based the interval value scale, which is constructed interactively with the decision maker [Bana e Costa et al., 2012]. However both technique, MACBETH and AHP are based on pairwise comparisons entered by the user, the MACBETH uses an interval scale, whereas AHP adopts a ratio scale [Saaty, 1980].

First, the decision-maker is asked to rank the elements of X by decreasing attractiveness. In situation, where it is difficult to rank directly elements of X he is asked to compare the elements in two steps procedure: is one of the two elements more attractive than the other and if yes, which one? When x is more attractive than y (xPy), the decision-maker is asked for a qualitative judgment about the difference of attractiveness between x and y, by presenting the decision maker with six categories[3]: C_1 – very weak difference *of attractiveness,* C_2 – weak difference *of attractiveness,* C_3 – moderate difference *of attractiveness*, C_4 – strong difference *of attractiveness*, C_5 – very strong difference *of attractiveness*, C_6 – extreme difference *of attractiveness.*

Judgmental disagreement or hesitation between two or more consecutive categories, except indifference, is also allowed. Some useful techniques were proposed to simplify judgment in MACBETH matrix [Sanchez-Lopez et al., 2012; Bana e Costa, Chagas, 2004; Bana e Costa et al., 2008]. One of the proposition is to enter the qualitative information into this matrix to the right of the matrix's main diagonal starting from the difference between the highest level (i.e. the most attractive) and the lowest level (i.e. the least attractive). Judging the difference of attractiveness between every two consecutive scale the main diagonal of the matrix was first completed. Next, decision-makers judge the difference of attractiveness between the first level and the third, the second level and the fourth and so on, thus completing the second diagonal of the matrix [Sanchez-Lopez et al., 2012]. The other technique was proposed by Bana e Costa and Chagas [2004]. The authors suggested make judgment from top to bottom the last column of the matrix, next to fill from right to left the first row, and finally to complete the main diagonal of the matrix. Bana e Costa et al. [2008] mentioned that both procedures are correct, however others are also possible. It is also worth nothing that it is not necessary to

[3] It is worth nothing, that however there is no restriction about the number of semantic categories to be used seven categories usually were used because of human limited perception and difficulties of evaluating simultaneously big numbers of options, when giving absolute value judgments.

perform all of the $\frac{n(n-1)}{2}$ paired comparisons to complete MACBETH matrix. It was shown that *n*-1 is the minimum acceptable number of judgments', which corresponds either to the last column or the first row or the main diagonal of the matrix. However, it is also recommended to perform some additional judgments in order to cross-check consistency [Bana e Costa et al., 2008; Sanchez-Lopez et al., 2012]. In the MACBETH matrix cell containing a "positive" difference of attractiveness means that, for those judgments, the information available is ordinal.

Problem of Consistency in MACBETH Matrix. There are two types of inconsistencies: *semantic*, when the assignment of category of difference of attractiveness to a pair of comparison is not logically acceptable and *cardinal* if the representation of the judgments is not possible through a cardinal scale within the real numbers. In general, for each paired comparison, M-MACBETH verify their consistency with regard to the judgments already available in the matrix uses an algorithm based on linear programming [Bana e Costa et al., 2005, 2012]. Each time that a qualitative judgment is elicited, M-MACBETH tests the consistency of all the judgments made by the decision maker, and their compatibility with cardinal information. A detailed study of the inconsistencies, the formal description of problem of inconsistency, types of inconsistencies as well consistency tests can be found in papers [Bana e Costa et al, 2005; Ishizaka, Nemery 2013].

Determination of MACBETH Scale. In the case of consistent matrix of judgments, the software will calculate the weights and scores of options by linear optimization which minimizes the score of the most attractive option/criterion. The least attractive option/ criterion is grounded to 0. The software propose a decision-maker scale which he can accept as the final scale. However, because several solutions may exist, software calculated also (by integer linear programming) "free interval" which can be used to modify scores of options if needed [Bana e Costa, Vansnick, 1995; Bana e Costa et al., 2005; Ishizaka, Nemery, 2013].

The Values Function. Finally, a process was accomplished in order to construct the corresponding *value functions*. The performance of the options on each criterion in the form of value score are transformed for value function. [Bana e Costa, Vansnick, 1995; Bana e Costa et al., 2005; Ishizaka, Nemery, 2013].

The Overall Score Measures. Next, options are evaluated globally using multi-criteria additive aggregation mode by calculating weighted average of the options scores on the criteria. This overall score measures the relative global attractiveness of the options across the entire set of criteria under consideration. Let us note that weights were also assigned to the criteria by a MACBETH weighting process [Bana e Costa, Vansnick, 1995; Bana e Costa et al., 2005; Ishizaka, Nemery, 2013].

2.2. M-MACBETH software

The M-MACBETH Decision Support System is based on the implementation of the MACBETH methodology[4]. **M-MACBETH** *is a multi-criteria decision support software that permits the structuring of value trees, the construction of criteria descriptors, the scoring of options in relation to criteria, the development of value functions, the weighting of criteria, and extensive sensitivity and robustness analysis about the relative and intrinsic value of options* [Bana e Costa et al., 2005b].

The **M-MACBETH** software allows model structuring through a "*value tree*" which useful and easy visual interface[5]. The questioning procedure is providing by verbal information about the difference of attractiveness of the options/criteria and the software tests the compatibility of the information collected with regard to information. The software gives a warning message about "*inconsistent judgments*". Then it provides the discussion with the decision-maker presenting, in this time, graphically the source of the problem and giving suggestions to deal with inconsistencies. After solving inconsistency, the software proposes a *numerical scale* with friendly graphic representation. The *numerical scale* is automatically transformed into a *scoring scale*. Criteria weights can be represented in a *bar chart of scores*. Finally, the M-MACBETH software aggregates the *scoring* and *weighting scales* in an *overall scale* of attractiveness as well proposes a graphic representation in the form of the *Overall Thermometer* which can be used for discussion and later analysis by decision maker.

The M-MACBETH software proposes also several additional tools which are very helpful for analyzing the obtained results. The tool *Difference profiles* shows graphically the difference between the profiles for any two options. The *XY Map* represents a two-dimensional graph comparing visually options with regards two selected criteria. The tool *Sensitivity analysis by weight* allows to observe the impact of the change on one criterion weight on the overall score, whereas *Robustness analysis* shows the impact ordinal or/and pre-cardinal intra-criteria and inter-criteria information in described model.

3. The negotiation model based on MACBETH approach

The important part of the pre-negotiation phase is evaluation negotiation offers and rankordering them using a *scoring function*. To formalize our model of negotiation we assume that negotiation problem is ill-structured, what means that problem itself as well the negotiation preferences cannot be precisely defined [Roszkowska et al. 2012, 2014]. However, a several multi-criteria decision making techniques can be used to support decision maker in negotiation [see: Salo, Hamalainen, 2010; Brzostowski et al, 2012a, 2012b; Wachowicz, et al, 2012; Wachowicz, Błaszczyk, 2012; Roszkowska et al., 2012, 2014] we propose here an effective application of the MACBETH approach and M-MACBETH software to handle ill-structured negotiation problems. What is one of

[4] A full tutorial *M-MACBETH* see http://www.m-macbeth.com/en/downloads.html. A free trial version program can be downloaded from http://www.m-macbeth.com/. This version is limited to five criteria and five options.

[5] For details see: [Bana e Costa at el., 2005b; *M-MACBETH…*, 2005; Ishizaka, Nemery, 2013].

the advantages proposed approach is that the MACBETH-based negotiation model makes possible to quantify preferences arising from a verbal evaluation of the quality of negotiation issues and building the scoring function for negotiation packages. The MACBETH can be used to analyze the structure of the negotiation problem, to determine the importance weights of the negotiations issues and to obtain the final ranking of the negotiation packages. To formalize our model we start with the following definitions:

- *a negotiation package* (*option*) is an offer, which negotiator may send to or receive from their opponent,
- *an issue* is a criterion negotiator use to evaluate the offers.

We assume that negotiator has to evaluate (or rank) m feasible packages P1, P2,…,Pm taking into consideration the set of n issues $Z = \{Z_1, Z_2,..., Z_n\}$ and vector of issue weights $w = [w_1, w_2,...., w_n]$. The process of formalizing negotiation model and preparing the negotiator's *scoring function* is described in a few steps as follows:

Step 1. Negotiation model structuring

1.1. The negotiation template. Negotiator define the negotiation problem, conducts a thorough analysis of the problem, identify of the objectives forthcoming negotiation and transform them into the negotiation issues. These objectives are the evaluation criteria of the potential negotiation contract. Negotiator define also a set of feasible dimensions which bounded by the lowest acceptable target value (reservation level) and an aspiration value (aspiration level), for each issues. These values give the maximum limit of demands as well as the minimum limit of concessions and define the negotiation space [Roszkowska et al., 2014].

Having such defined negotiation template negotiator implemented M-MACBETH software to elicit the preferences and generate the *scoring function* of the negotiation offers. The next steps are strictly based on M-MACBETH software [for details see: *M-MACBETH*…, 2005].

1.2. Negotiation issues. The decision-makers have to **s**tructure the goals of negotiation and identify the negotiation issue (criteria) in value tree. In general, M-MACBETH tree is formed by two different types of modes such as "*criteria modes*" and "*non-criteria*" modes. Non-criteria nodes are included in the tree to help with the evaluation of criteria nodes but are not directly influential in the decision (because they act as comments to structure the problem). In evaluation phase, only "*criteria modes*" are used to assign the numerical score to each package.

Next, the decision-makers have to identify the few most relevant sub-levels of a given negotiation issue to describe their performance in the scale from the most attractive to the least. In order to measure the attractiveness of package, it is required to construct a value function for every evaluation criteria in the model. The criterion mode can be entering with direct or indirect bases of comparison. The choice of the evaluation technique: direct and indirect comparison needs to be done by decision-makers when setting the criterion nodes. We have two bases for direct comparison [Bana Consalting, 2005]:

1. *"pairwaise comparison packages only among themselves"* ;
2. *"pairwise comparison each package to two benchmark references"*.

The M-MACBETH offers also two indirect bases for comparison:

1. "*qualitative performance levels*"
2. "*quantitative performance levels*".

However, a choice between direct and indirect technique depends on decision- makers, from the perspective of negotiation analysis and application M-MACBET indirect bases for comparison technique seems more adequate and recommended to support ill-structure negotiation[6]. The pairwaise comparisons packages only among themselves might be difficult as well time-consuming in case of many packages. But, if anyway a decision-maker choses direct comparisons, pairwise comparison with regards benchmark references gives him an opportunity to compare packages with two reference points: *ideal package*-determined by all aspiration levels and *anti-ideal package* determined by all reservation levels.

The other advantage of indirect comparison is the fact that it is easier to evaluate attractiveness sub-levels of issues and weights and next aggregate them. Such approach allows us also for numerical and visual analyses obtained results by friendly M-MACBETH tools us such as: *Difference profiles*, The *XY Map, Sensitivity analysis by weight* and *Robustness analysis* which is very helpful in forthcoming negotiation process.

In the case of indirect comparison, the packages are evaluated by *value function* which converts any level performance on the issue into numerical score. The basic of comparisons with respect to criteria are selected sub-levels for each issue. The aspiration level and reservation level, for each issue, are coded as "*upper reference level*" and "*lover reference level*" in M-MACBETH procedure.

1.3. Negotiation packages. During this phase, decision-makers have to define the negotiation packages to be evaluated as well as their performances. The approach starts with the identification, for each issue, the few most important sub-levels (objects) to be considered in the scale and to decide if those performance sub-levels can be described qualitatively or quantitatively. Next the classification of the selected objects in order of attractiveness from the most to the least attractive is provided where equal rankings or ties are also allowed.

The next step is to assemble all possible combinations of sub-levels of performance identifying possible combinations in the form of negotiation packages regarded as potential negotiation offers. The packages can be obtained by the comparisons of sub-levels between aspiration and reservation level with respect to those criteria. Finally, the negotiator specifies the preliminary set of feasible packages $P = \{P1, P2,..., Pm\}$ in the form of the *Table of Preferences*. In the case where the bases for comparison of the all criteria are given in the forms of qualitative/quantitative performance levels the conversion of a package's performance into a score will require that the package's performance be enter into the model. After the phase **negotiation model structuring**, three types of scores have to be calculated: *scores of*

[6] The negotiation model proposed in this paper is based on *indirect bases for comparison*, however the direct bases of comparison is also possible.

options which represent the attractiveness of a package to one specific issue, *weighting criteria* which measure the attractiveness of each issue in relation to the top goal of negotiation, and *overall score of options* (*scoring function*) where issue weight and option scores are only intermediate results used to calculate the overall score of package (*value of scoring function of the package).* While the score of options ranks packages with regard to a single issue, the overall score of packages, i.e. *scoring function,* ranks them with regard to all issues and consequently to the overall goal of negotiation.

Step 2. Evaluation of packages

2.1. Scoring of packages with respect to each issue. Here, the decision-makers have to evaluate each package attractiveness with regards to each issue in the form of MACBETH judgment matrix. The questioning procedure appears on verbal information about the difference of attractiveness between the pairs of objects (sub-levels) issue at a time with application seven semantic categories: difference of attractiveness. (e.g. "no", "very weak", "weak", "moderate", "strong", "very strong" and "extreme"). The MACBETH can also function with the minimum of *n*–1 responses (in general the diagonal line of successive pairs), based on the hypothesis that the difference for the other pairs is positive.

For each of the answers about a new pair of objects, the software tests the compatibility of the information collected with regard to cardinal information, verifies its compatibility with the judgment previously inserted in the matrix. In the situation of incompatible judgments, the software gives a message about inconsistent judgments, shows the source of the incompatibility and gives a proposition of solving problem in friendly discussion with a decision-maker.

When judgment is consistent M-MACBETH software can propose a numerical scale (*current scale* column) which is compatible with the verbal expressions provided (i.e. this scale is the results of the conversion of the verbal expressions into numerical values). These scores are based on a scale ranking from zero (the reservation level) to 100 (the aspiration level). The M-MACBETH proposes a representative score and indicates also the *interval* of the compatible values with the verbal evaluations. Thus, the decision maker can use any value from the interval that seems most appropriate for him while remaining consistent with the verbal evaluation. What is useful, the software presents a graphic representation of the proposed *scale* and friendly tools that allow its transformation into a *cardinal scale*. We can see an interval within which the score of a performance level can be changed while keeping fixed the scores of the remaining performance levels and maintaining the compatibility with the matrix judgment.

The software proposed two graphical visualization: a vertical axis in which each proposed scorer is plotted at the same point as the respective quantitative level and the picewise-linear value function's graph where the performance levels are plotted on the horizontal axis and the scores on the vertical axis. What is also worth noting the linear pieces serve to calculate the score of any package where performance with respect to the issue is between consecutive performance levels.

2.2. Weighing the negotiation issues. The ranking of issues weights is determined by ranking the overall references in terms of their overall attractiveness. Next the weights scale is build from the weighing matrix of judgment. We have also interval within with the weight can be changed while maintaining the compatibility with the weighing matrix of judgment.

Step 3. The creating scoring function (overall scores) and analyses the score results

3.1. The scoring function (overal scores). The M-MACBETH software has a module that aggregates the scoring and weighting scales in an overall scale of attractiveness, so create *scoring function* for evaluation negotiation packages. The overall attractiveness (*scoring function*) of packages is obtained through an additive aggregation model. The software presents the summarized information within a *Table of scores* and proposes a graphic representation in the form of *The Overall Thermometer* which is useful for later discussion and analysis.

3.2. The analysis the scores results. In order to better understanding of the model results the M-MACBETH allow to observe how a *package issue* scores contribute to its *overall package scores*. Each criterion bar in the weighted profile of the option (package) corresponds to the product of criterion weight and the option's (package's) score on the criterion (issue). We can easy specify negative contribution situation where the second of the two selected packages issues outperformed the first one, positive contribution situation, where the first of the two selected packages issue outperformed the second one or the null difference if the two packages are indifferent in the issue. *The weighed bar* allows to analyze the possibilities of compensation one options by another. The M-MACBETH offered graphical representation model's results in a two dimensional graph (*XY map*), which enable to compare the option's scores in two criteria or group of criteria. *Sensitivity analysis on criterion weight* gives useful visualization the effects of a change in its weight on the packages scores and *Robustness analysis* allows for discussion about impact ordinal or/and pre-cardinal intra-criteria and inter-criteria information in negotiation model.

4. Numerical example

Let us now consider a buyer-seller negotiation that allows us to show how the proposed MACBETH-based model and M-MACBETH software can support one of the negotiator (Seller) in scoring negotiation offers. Let as assume that Seller and Buyer negotiate the conditions of the potential business contract and three issues are discussed: *price*, *time of payment* and *returns conditions*.

Step 1. Negotiation model structuring

1.1. The negotiation template. Let as assume that Seller and Buyer negotiate 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 space for Z_1, Z_2 are defined by numerical values and for Z_3 by linguistic values.

- Price (EUR): $\langle 20, 30 \rangle$ for both parties;
- Payment (days): $\langle 3, 22 \rangle$ for both parties,
- Returns: defined qualitatively taking into account % defects and % penalty.

To build the initial set of packages in the pre-negotiation phase Seller defines the salient options for each issue in the following way:

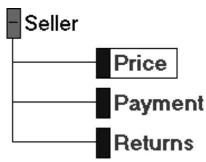
- Price: 30, 25, 23, 20.
- Payment: less than 3 (days), 4-7 (days), 8-14 (days), 15-21 (days), more than 22 (days)
- Returns: 5% defects and 2% penalty, 5% defects and 4% penalty, 7% defects and 4% penalty

Having such defined negotiation template Seller implemented M-Macbeth software to elicit the preferences and generate the scoring system of the negotiation offers. We testify practically all steps of Sellers preference analysis to show usefulness M-Macbeth software in supporting negotiation.

1.2. Negotiation issues (criteria). For simplicity, in our example, all modes are "criteria modes". The value tree for the Seller is presented on the Figure 1.

FIGURE 1.

The "value tree" for the Seller



Source: Own elaboration based on M-MACBET software.

Let us assume that the basic of comparisons with respect to criteria are salient sub-levels for each issue. The "*upper reference lever*" and "*lover reference level*" are represented by aspiration level and reservation level. Thus we have the following:

- *Price: – qualitative performance levels*

  Basis for comparison: 25, 20, 23 (EURO).

  References points: Upper reference level: Aspiration level – 30 (EURO), Lower reference level: Reservation level – 20 (EURO);
- *Payment – qualitative performance levels*

  Basis for comparison: 4–7 (days), 8–14 (days),14– 21 (days);

References points: Upper reference level: Aspiration level – less than 3 (days), Lower reference level: Reservation level – more than 22 (days);

– *Returns – qualitative performance levels*

Basis for comparison: levA: Aspiration level, lev1: 5% defects and 2% penalty, lev2: 5% defects and 4% penalty, lev3: 7% defects and 4% penalty, levR: Reservation level

References: levA: Aspiration level, levR: Reservation level

1.3. **Negotiation packages**. Let us assume that the preliminary set of feasible packages $P = \{P1, P2, ..., P10\}$ consist of ten packages which are represented in the form of the *Table of Preferences* (see Figure 2).

FIGURE 2.

***The Table of Preferences* for the Seller**

Table of performances

Options	Price	Payment	Returns
P1	30	14-21 (days)	lev2
P2	25	8-14 (days)	lev1
P3	25	4-7 (days)	lev3
P4	25	8-14 (days)	lev2
P5	25	8-14 (days)	lev3
P6	23	14-21 (days)	lev1
P7	23	4-7 (days)	lev1
P 8	23	4-7 (days)	lev3
P9	23	8-14 (days)	lev2
P10	20	4-7 (days)	lev1

Source: Own elaboration based on M-MACBET software.

Step 2. Evaluation of negotiation packages

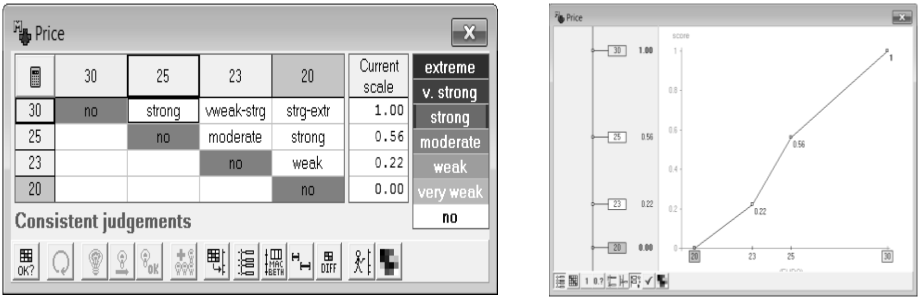
2.1. Scoring of packages with respect to each issue. Matrix of judgments for performance levels and MACBETH numerical scale of issue "*Price*" are presented on the Figure 3. Let us remember that only $n - 1$ independent evaluation are required and others can be deduced by transitivity. However, it is better to fill the upper triangle of the matrix using the semantic categories. In the case, where the decision-maker is unsure about the exact category, he can select two or more successive categories as in Figure 3., where the difference between price 30 and 23 is evaluated from *week to strong.*

Matrixes of judgments for performance levels and MACBETH numerical scales of issues "*Time*" and "*Returns*" are presented in the Figures 4 and 5.

It is worth noting that all the scores can to be readjusted, in this same time being compatible with the judgment provided in the matrix. The permissible interval for 4-7 days is shown in red on the left part of the *Scale* on the Figure 4. Decision maker can feel free to use the value from the interval that seems for him most appropriate. In our example, however the score value suggested by M-MACBETH was accepted without modification.

FIGURE 3.

Price: Numerical and graphical display of a precardinal scale



Source: Own elaboration based on M-MACBET software.

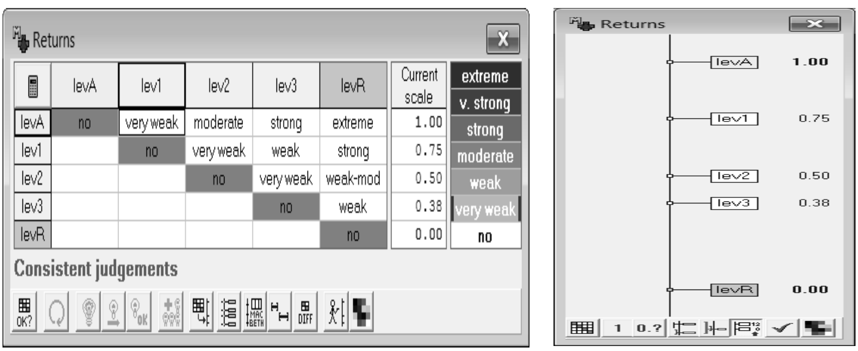
FIGURE 4.

Payment: Numerical and graphical display of a precardinal scale

Source: Own elaboration based on M-MACBET software.

FIGURE 5.

Returns: Numerical and graphical display of a precardinal scale

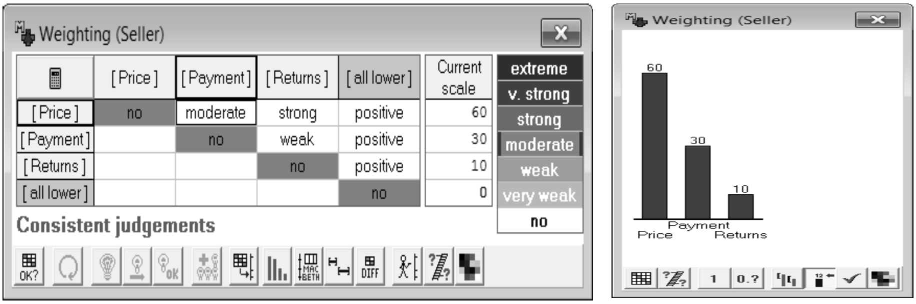


Source: Own elaboration based on M-MACBET software.

2.2. **Weighing the issues.** The judgment matrix for issue weights are presented on the Figure 6.

FIGURE 6.

Weights: Numerical and graphical display of a precardinal scale



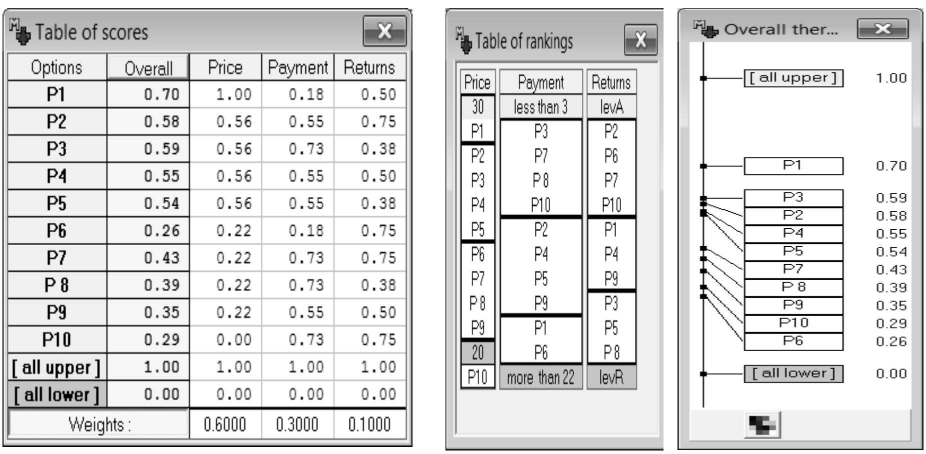
Source: Own elaboration based on M-MACBET software.

Step 3. The scoring function of packages and analyse the score results

3.1. The scoring function (overal scores). Numerical and graphical display of a scoring points (*overall scores*) for evaluated negotiation packages are presented on the figure 7. The *Table of scores* contains the overall scores for packages and scores with regard to each issue.

FIGURE 7.

Table of scores. Numerical and graphical display of a Overall scores



Source: Own elaboration based on M-MACBET software.

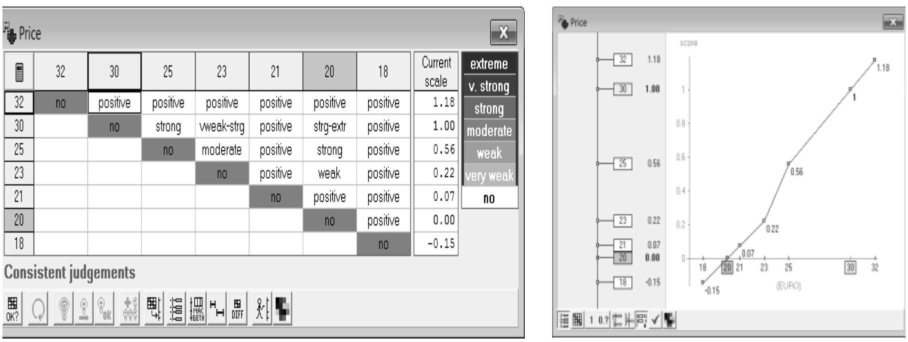
Let us assume now that during negotiation process negotiator can search and construct new packages and evaluate it using *scoring function*. The optimal *scoring function* should produce consistent ranking after new packages are added (or removed) and should not provide to rank reversal [García-Cascales, Lamata, 2012; Schenkerman, 1994]. This means that in the case of adding or removing new package the negotiator does not need to re-evaluate the previously evaluated packages, as well the score points of all packages are stable.

We can see that the M-MACBETH approach allows, under same conditions, introducing to a set of packages new ones without rescoring other packages. Let us introduce three new prices: 18, 21, 32 to the basic of comparison for criterion *Price,* where price 18 is under reservation level, 32 is over aspiration level, 21 is from negotiation space. We introduce also new sub-level in Returns conditions: Level 4: 3% defects and no penalty.

In the case of quantitative issues *Price* M-MACBETH can estimate score based on the previous scale. In this case, the new judgment matrix is even not necessary if decision maker can agree for the M-MACBETH software approximation. But it is possible make judgment matrix without changing the previous scale. In all cases where the minimal information was used the judgment is consistent as well stable with respect to previous scores. The judgment of differences of attractiveness within a issue "*Price*" is presented on the Figure 8 and judgment within "*Returns*" in Figure 9.

FIGURE 8.

Price: Numerical and graphical display of a precardinal scale.

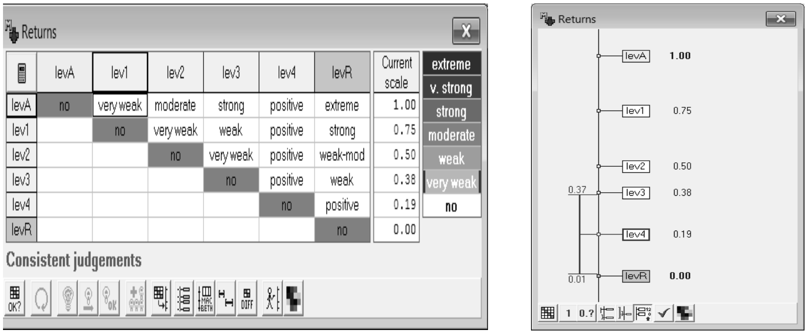


	32	30	25	23	21	20	18	Current scale
32	no	positive	positive	positive	positive	positive	positive	1.18
30		no	strong	vweak-strg	positive	strg-extr	positive	1.00
25			no	moderate	positive	strong	positive	0.56
23				no	positive	weak	positive	0.22
21					no	positive	positive	0.07
20						no	positive	0.00
18							no	-0.15

Source: Own elaboration based on the M-MACBET software.

FIGURE 9.

Returns: Numerical and graphical display of a precardinal scale



	levA	lev1	lev2	lev3	lev4	levR	Current scale
levA	no	very weak	moderate	strong	positive	extreme	1.00
lev1		no	very weak	weak	positive	strong	0.75
lev2			no	very weak	positive	weak-mod	0.50
lev3				no	positive	weak	0.38
lev4					no	positive	0.19
levR						no	0.00

Source: Own elaboration based on M-MACBET software.

Let us assume that the decision-makers have to take into account five new negotiation packages P11, P12, P13, P14, P15 obtained by using new basic on comparisons with respect to issue *Price* and *Returns*. The new *Table of Preferences* as well *Table of Scores* and *Overall Thermometer* were presented on the Figure 10.

We can see that M-MACBETH allows for evaluation of new packages which are outside negotiation space (over-good or under-bad with regards to some issues), to provide discussion about compensation. Let us observe thethat new package P14 is the most attractive, packages P11, P15 are less attractive and packages P12, P13 are the least attractive.

FIGURE 10.

Table of preferences. Table of scores and Overall Thermometer

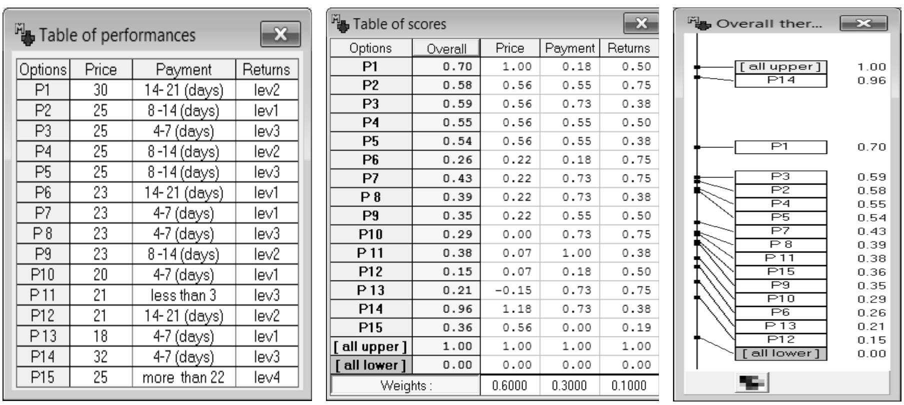


Table of performances

Options	Price	Payment	Returns
P1	30	14-21 (days)	lev2
P2	25	8-14 (days)	lev1
P3	25	4-7 (days)	lev3
P4	25	8-14 (days)	lev2
P5	25	8-14 (days)	lev3
P6	23	14-21 (days)	lev1
P7	23	4-7 (days)	lev1
P 8	23	4-7 (days)	lev3
P9	23	8-14 (days)	lev2
P10	20	4-7 (days)	lev1
P 11	21	less than 3	lev3
P12	21	14-21 (days)	lev2
P 13	18	4-7 (days)	lev1
P14	32	4-7 (days)	lev3
P15	25	more than 22	lev4

Table of scores

Options	Overall	Price	Payment	Returns
P1	0.70	1.00	0.18	0.50
P2	0.58	0.56	0.55	0.75
P3	0.59	0.56	0.73	0.38
P4	0.55	0.56	0.55	0.50
P5	0.54	0.56	0.55	0.38
P6	0.26	0.22	0.18	0.75
P7	0.43	0.22	0.73	0.75
P 8	0.39	0.22	0.73	0.38
P9	0.35	0.22	0.55	0.50
P10	0.29	0.00	0.73	0.75
P 11	0.38	0.07	1.00	0.38
P12	0.15	0.07	0.18	0.50
P 13	0.21	-0.15	0.73	0.75
P14	0.96	1.18	0.73	0.38
P15	0.36	0.56	0.00	0.19
[all upper]	1.00	1.00	1.00	1.00
[all lower]	0.00	0.00	0.00	0.00
Weights :		0.6000	0.3000	0.1000

Source: Own elaboration based on M-MACBET software.

Now, using M-MACBET software selected analysis obtained results will be done graphically from the perspective usability to forthcoming process of extending offer. The difference between the profiles for any two packages can be viewed by *Difference* *profiles*. Let us observe that each criterion bar in the weighted profile of the negotiation package corresponds to the product of issues scores and the sub-levels scores on this issue. For example, in Figure 11 the package P1 is compared to the package P5. The package P1 out performed overall the package P5 with 0.17 score points. However, the package P1 out performed in package P5 with regards to the issue *Price* with 0.26 score points as well issue *Returns* with 0.01 score points. On the other hand, package P5 out performed in package P1 in with regards issue *Payment* with 0.26 score points. The weighed bars allows to analyze the extent to which the differences in favor of the one issue compensate, or not, the differences in of the others issues.

FIGURE 11.

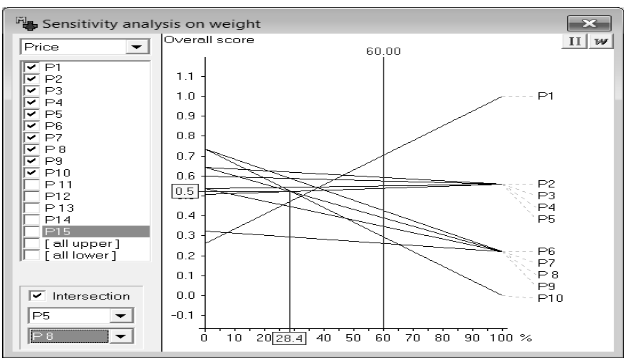
Profile differences

Source: Own elaboration based on M-MACBET software.

The M-MACBETH software allows *sensitivity analyses* to be performed. All changes on scores and weights are instantaneously reflected upon all other dependent values and graphics. The sensitivity analysis on weight is presented on the Figure 12. We can see rankordeing ten selected packages in the case of changing weight for issue *Price*.

FIGURE 12.

Sensitivity analysis on the weight

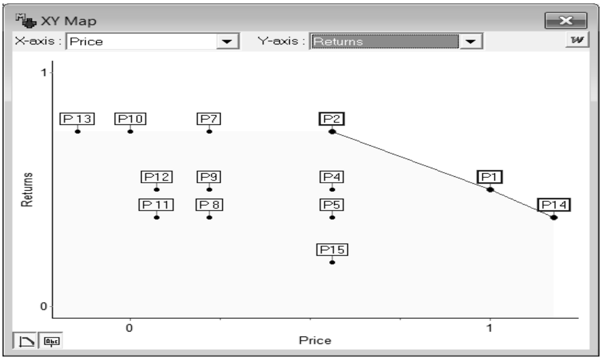


Source: Own elaboration based on M-MACBET software.

We can also analyze the results of *scoring function* graphically by using a two-dimensional graph (*XY Map*), where each axis represents negotiation issue In Figure 13., the packages are presented according to their attractiveness on the *Price* and *Returns* issues. We can see that the package P13 has a good *Returns* condition but is not attractive on the *Price* issue. On the other hand, the package P15 has an attractive *Price* and a not good *Returns* conditions. On the red line which represent the efficient frontier we can found P1, P2, P14 as dominated packages.

FIGURE 13.

Comparison of scores on two issues: Price and Returns



Source: Own elaboration based on the M-MACBET software.

5. Conclusion

In the paper a framework for the evaluation of negotiation offers based on MACBETH methodology and M-MACBETH software have been proposed. The MACBETH technique were used to structure negotiation problems by defining numerical values based on verbal statements which enables the construction of value functions derived from qualitative judgments about the difference of attractiveness between every two performance levels of the negotiation scale. Such approach allow us to quantify preferences arising from a verbal evaluation of the quality of negotiation option or negotiation issues and calculate the attractiveness (scores) of the negotiation packages in numerical way. It shows how M-MACBETH can be used to construct an additive evaluation model based on qualitative value judgments of difference in attractiveness.

The main key advantages of the MACBETH approach are the following:

1. This technique allow for verbal preference elicitation attractiveness of packages with procedure that transform *ordinal* information for *cardinal information* by a non-numerical *pairwise comparison* questioning mode. It is very useful approach especially were problem is poorly defined, in the context of qualitative issues which often appear in negotiation template, as well in the case of imprecise information.
2. This same M-MACBETH technique can be used to measure attractiveness of negotiation issues as well weight of sub-levels of issues.

3. The computation processes of determining the scoring function take into account the negotiation space of each issue as well the concepts of reservation and aspiration levels.
4. The verbal negotiator expressions sometimes could be vague, so the representative score generated by the MACBETH is accompanied by the value of the interval within which it is located. The M-MACBETH software proposed *exact score* however the negotiator can modify *preference scale* using points form interval scale if needed.
5. The MACBETH procedure makes possible to expand the negotiation template by introducing new package after the preference elicitation has been conducted (within or outside the actual negotiation space) without modifying ranking preliminary estimated packages. That means that proposed *scoring function* produces consistent ranking after new packages are added (or removed) and does not provide to rank reversal.

The main advantages of the M-MACBETH software are the following: this questioning procedure is straightforward and friendly for decision maker, allow for useful visualizations results, checks the consistency of judgment, proposed solution in the case of inconsistency providing simple discussion with decision maker, allows for useful sensitive analysis, offers a few interesting tools for visualization results evaluation negotiation packages which are very helpful in phase of forthcoming negotiation.

The disadvantages of the MACBETH technique is fact that the MACBETH procedure is time-consuming, so it is practically usable only if the number of criteria and alternatives is sufficiently low, usually not higher than 9.

Our future work will be focused on modifying the M-MACBETH approach to be more useful for evaluation negotiation offers in ill structure negotiation problems. One of the proposition is comparing MACBETH with other verbal technique such as ZAPROS [Górecka et al., 2014]. It could be also powerful, from the perspective negotiation analysis, to combine MACBETH with TOPSIS technique or extend MACBETH in fuzzy environment.

Bibliography

Bana e Costa C.A., Beinat E. 2005 *Model-Structuring in Public Decision-Aiding* (LSEOR 05.79), The London School of Economics and Political Science, London.

Bana e Costa C.A., Chagas M.P. 2004 *A Career Choice Problem: an Example of ow to Use MACBETH to Build a Quantitative Value Model Based on Qualitative Value Judgments*, "European Journal of Operational Research", 153(2), 323-331.

Bana e Costa C.A., De Corte J.M., Vansnick J.C. 2003 *MACBETH*, The London School of Economics and Political Science, London.

Bana e Costa C.A., De Corte J.M., Vansnick J.C. 2005a *On the Mathematical Foundations of MACBETH*, [in:] *Multiple Criteria Decision Analysis: State of the Art Surveys*, J. Figueira, S. Greco, M. Ehrgott (eds.), Springer, New York 409-442.

Bana e Costa C.A., De Corte J.M., Vansnick J.C. 2005b *Software M-MACBETH Version 1.1*, Copyright European Working Group "Multiple Criteria Decision Aiding", Série 3, nº12, automne 2005. Series 3, nº 12, Fall.

Bana e Costa C.A., De Corte J.M., Vansnick J.C. 2012 *MACBETH*, "International Journal of Information Technology & Decision Making", Vol. 11, No. 2, 359-387, DOI: 10.114 2/S0219622012400068.

Bana e Costa C.A., Vansnick J.C. 1994 *MACBETH – an Interactive Path towards the Construction of Cardinal Value Functions*, "International Transactions in Operational Research", 1(4), 489-500.

Bana e Costa C.A., Vansnick J.C. 1995 *General Overview of the Macbeth Approach*, [in:] *Advances in Multicriteria Analysis*, P.M. Pardalos et al. (eds.), Kluwer Academic Publishers, Dordrecht, 93-100.

Bana e Costa C.A., Vansnick J.C. 1999 *The MACBETH Approach: Basic Ideas, Software, and an Application*, [in:] *Mathematical Modelling: Theory and Applications: Vol. 4. Advances in Decision Analysis*, N. Meskens, M. Roubens (eds.), Kluwer Academic, Dordrecht, 131-157.

Brzostowski J., Roszkowska E., Wachowicz T. 2012 *Supporting Negotiation by Multi-Criteria Decision-Making Methods*, "Optimum. Studia Ekonomiczne", nr 5(59).

Brzostowski J., Wachowicz T., Roszkowska E. 2012 *Using an Analytic Hierarchy Process to Develop a Scoring System for a set of Continuous Feasible Alternatives in Negotiation* , "Operations Research and Decisions", No. 421-40

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

Górecka D., Roszkowska E., Wachowicz D. 2014 *MARS – a Hybrid of ZAPROS and MACBETH for Verbal Evaluation of the Negotiation Template*, Group Decision and Negotiation 2014, GDN 2014, Proceedings of the Joint International Conference of the INFORMS GDN Section and the EURO Working Group on DSS, Zaraté P., Camilleri G., Kamissoko D., Amblard F. (eds.), Toulouse University, Toulouse, 24-31.

Ishizaka A., Nemery P. 2013 *Multi-Criteria Decision Analysis. Methods and Software*, Wiley, United Kindgdom

M-MACBETH Version 1.1: User Manual 2005, Bana Consulting, Lisbon.

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

Roszkowska E., Brzostowski J., Wachowicz T. 2014 *Supporting Ill-Structured Negotiation Problems*, Human-Centric Decision-Making Models for Social Sciences, G. Peijun, W. Pedrycz, (eds.) Springer, London, 339-367.

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

Roszkowska E., Wachowicz T. 2014 *The Multi-Criteria Negotiation Analysis Based on the Membership Function*, "Studies in Logic, Grammar and Rhetoric", Mechanisms and Methods of Decision Making (ed. E. Roszkowska) 37(50), 195-217.

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

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

Sanchez-Lopez R., Bana e Costa C., De Baets B. 2012 *The MACBETH Approach for Multi-Criteria Evaluation of Development Projects on Cross-Cutting Issues*, "Ann Oper Res", 199, 393-408 , DOI 10.1007/s10479-011-0877-4

Schenkerman S. 1994 *Avoiding Rank Reversal in AHP Decision-Support Models*, "European Journal of Operational Research", 74, 407-419.

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

Wachowicz T., Błaszczyk P. 2012 *TOPSIS Based Approach to Scoring Negotiating Offers in Negotiation Support Systems*. "Group Decision and Negotiation", DOI: 10.1007/ s10726-012-9299-1.

Wachowicz T., Brzostowski J., Roszkowska E. 2012 *Reference Points-Based Methods in Supporting the Evaluation of Negotiation Offers*, "Operations Research and Decisions", No. 4, 121-137.