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APPLICATION OF TOPSIS METHODOLOGY TO THE SCORING OF NEGOTIATION ISSUES MEASURED ON THE ORDINAL SCALE

Abstract

The aim of this paper is to apply TOPSIS method for negotiation support. The support we focus on concerns the pre-negotiation preparation and the process of negotiation template evaluation, which results in building a scoring system for the negotiation offers. Since the negotiation template may contain different types of criteria (negotiation issues), both quantitative (price, time) and qualitative (verbal description of warranty), the mechanisms of measuring distances for different types of data need to be incorporated into TOPSIS scoring procedure. We will use GDM (generalized distance measure) for interval and ordinal data. For weakly structured negotiation templates an alternative approach is proposed, one that does not use pair-wise comparisons of the evaluated alternatives. To illustrate the performance of TOPSIS in negotiation support we present a numerical example of business negotiations.

Keywords

Negotiation support, negotiation template, preference elicitation, TOPSIS, interval scale, generalized distance measure.

Introduction

Many researchers and negotiation practitioners emphasize that the strategic element of negotiations, that influence the following process of exchanging offers and outcomes, is negotiation preparation that should be conducted within the pre-negotiation phase [Thompson 1998, Lewicki et al., 1999]. One of the key elements of the pre-negotiation phase is negotiation template building [Raiffa et al., 2002]. Negotiation template specifies the structure of the potential decision problem negotiators face. It contains the definition of the issues under consideration (equivalent to criteria defined in decision making problem) and options (potential resolution levels defined for each criterion). A well defined negotiation template helps negotiator to identify the negotiation space and support them in searching the compromise.

The negotiation template should be built jointly by negotiators during the pre--talks conducted in the pre-negotiation phase. However, some negotiation problems may be too complicated or the negotiators may wish not to reveal any of their position or goals, so the template cannot be well defined. No matter how well the template is defined, it should be scored, which will help negotiators to evaluate the offers proposed later in actual negotiation phase. The offer scoring process corresponds in fact to the negotiator's preference elicitation, therefore typical multiple attribute decision making procedures and algorithms are usually proposed to score the template. The additive scoring model [Keeney and Raiffa, 1976] is most often used. It has already been successfully applied in electronic negotiation support systems, such as Inspire [Kersten and Noronha, 1999], SmartSettle [Thiessen and Soberg, 2003], Negoisst [Schoop et al., 2003] or NegoCalc [Wachowicz 2008] and used for supporting real world problems, such as First Nations Negotiations in Canada [Thiessen and Shakun, 2009]. The additive scoring model is methodologically a simple tool, but it requires from decision makers (negotiators) the definition of their preferences for each single resolution level (issue option), that can be used for building the decision alternatives (offers). It is easy to conclude that for large decision problems the multitude of the score assignments may be tiresome and discouraging for decision maker. Therefore other methods for scoring a negotiation template are proposed. AHP [Saaty, 1980] is suggested frequently as an alternative to the additive scoring model [Mustajoki and Hamalainen, 2000; Wachowicz, 2008a]. In AHP the preference elicitation approach is different and is based on pair-wise comparisons of all atomic elements of the decision process and the subsequent preference aggregation. For large decision problems it may be, however, as tiresome as the additive scoring model and may result in ranking reversal if the negotiation space changes. Other methods and models have been also proposed for scoring templates, such as rule-based models [Chen et al., 2004], simulation [Matwin et al., 1989] or ELECTRE-TRI [Wachowicz, 2010], but all of them require either professional mathematical (or decision making) knowledge of negotiators or very complicated calculations that make the elicitation process not transparent to the decision maker.

In this paper we propose an alternative approach for elicitation of the negotiator's preferences that allows for scoring the negotiation template quickly and reduce the negotiator's workload and involvement in the scoring process. It is based on a straightforward statistical method and calculates the offers scores using their distances from the ideal and negative ideal solutions. The approach is based mostly on TOPSIS [Hwang and Yoon, 1981], however, the method needs to be modified to allow the ordinal variables (issues) to be taken into account. In this modification the notion of a generalized distance measure [Walesiak, 2002] and measuring distances for various types of variables [Bock and Diday, 2000] is mainly used. Two alternative procedures GDM-TOPSIS and TOPSIS-WDT are proposed for evaluating well and weakly defined templates respectively. In the following sections we give a brief review of TOPSIS (Section 2) and propose the TOPSIS modifications (Section 2). Then an algorithm for negotiator's preference elicitation is proposed (Section 3) and the examples of GDM-TOPSIS and TOPSIS-WDT algorithm are presented. We conclude with some final remarks and future work required.

1. Foundations of TOPSIS

TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) was developed by Hwang and Yoon [1981] and later widely described with its modifications and adjustments [see Hwang et al., 1993; Lai et al., 1994]. It allows to build a ranking of alternatives described by a number of criteria. The underlying principle of TOPSIS is a bipolar comparison of each alternative under consideration with both the positive ideal (PIS) and the negative ideal (NIS) solutions. The distances to these two solutions are calculated for each alternative and then the aggregated criterion is built that combines these two factors and describes the quality of each alternative, assuming that the chosen alternative should have the shortest distance to the ideal solution and the farthest distance to the negative ideal one.

To conduct TOPSIS analysis we assume that the decision making problem is presented in the form of a matrix:

	C_1	C_2	…	C_n
A_1	x_{11}	x_{12}	…	x_{1n}
A_2	x_{21}	x_{22}	…	x_{2n}
…	…	…	…	…
A_m	x_{m1}	x_{m2}	…	x_{mn}

where A_j describes the alternative j under consideration ($j = 1, \dots, m$), C_k describes the criterion k for measuring the alternatives' performance ($k = 1, \dots, n$) and x_{jk} is the resolution level (performance) of alternative A_j with respect to criterion C_k. Furthermore, the criteria importance is specified in the form of a vector of weights $w = (w_1, w_2, \dots, w_n)$, where $\sum_{k=1}^{n} w_k = 1$. Let us assume, for each criterion C_k, without loss of generality, that a higher value of the alternative's performance is more preferred by the decision maker. In other words, we face the problem of vector maximization.

Having the decision making problem described as above, we can conduct the TOPSIS analysis for building the ranking of the alternatives. The TOPSIS algorithm consists of six subsequent steps:

1. Building the normalized decision matrix:

$$N = \begin{bmatrix} \widehat{x}_{11} & \widehat{x}_{12} & \cdots & \widehat{x}_{1n} \\ \widehat{x}_{21} & \widehat{x}_{22} & \cdots & \widehat{x}_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ \widehat{x}_{m1} & \widehat{x}_{m2} & \cdots & \widehat{x}_{mn} \end{bmatrix} \tag{1}$$

where:

$$\widehat{x}_{jk} = \frac{x_{jk}}{\sqrt{\sum_{j=1}^{m} x_{jk}^{2}}}, \tag{2}$$

for $j = 1, \dots, m$ and $k = 1, \dots, n$*.

2. Computing the weighted normalized decision matrix:

$$V = \begin{bmatrix} w_1\widehat{x}_{11} & w_2\widehat{x}_{12} & \cdots & w_n\widehat{x}_{1n} \\ w_1\widehat{x}_{21} & w_2\widehat{x}_{22} & \cdots & w_n\widehat{x}_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ w_1\widehat{x}_{m1} & w_2\widehat{x}_{m2} & \cdots & w_n\widehat{x}_{mn} \end{bmatrix} = \begin{bmatrix} v_{11} & v_{12} & \cdots & v_{1n} \\ v_{21} & v_{22} & \cdots & v_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ v_{m1} & v_{m2} & \cdots & v_{mn} \end{bmatrix}. \tag{3}$$

3. Determining the positive ideal (A^+) and negative ideal (A^-) solutions:

$$A^+ = (v_1^+, v_2^+, \dots, v_n^+), \text{ where } v_k^+ = \max_j(x_{jk}), \text{ for } k = 1, 2, \dots, n \tag{4}$$

$$A^- = (v_1^-, v_2^-, \dots, v_n^-), \text{ where } v_k^- = \min_j(x_{jk}), \text{ for } k = 1, 2, \dots, n \tag{5}$$

4. Calculating the separation measures (distance) for each alternative from PIS (d_j^+) and NIS (d_j^-) respectively:

$$d_j^+ = \sqrt[p]{\sum_{k=1}^{n} \left| v_{jk} - v_k^+ \right|^p}, \text{ for } j = 1, 2, \dots, m \tag{6}$$

$$d_j^- = \sqrt[p]{\sum_{k=1}^{n} \left| v_{jk} - v_k^- \right|^p}, \text{ for } j = 1, 2, \dots, m \tag{7}$$

* Apart from the above vector normalization procedure other normalization procedures are also proposed, such as different types of linear normalization or non-monotonic normalization and their effects on the final ranking results is studied [see Hwang and Yoon, 1981, Milani et al., 2005]. One of them will be proposed later in Section 2.2.

where p is the distance coefficient. Usually, the Euclidean distance is used in TOPSIS analysis, for which $p = 2$*.

5. Determining the relative closeness of each alternative to the ideal solution:

$$S_j = \frac{d_j^-}{d_j^+ + d_j^-}, \quad \text{for } j = 1, 2, \ldots, m. \tag{8}$$

where $0 \le S_j \le 1$. The closer the alternative A_j to PIS is, the larger the value of S_j.

6. Ranking the alternatives in descending order using S_j.

As can be derived from the above algorithm, to use the TOPSIS effectively the problem under consideration should be well structured and described with quantitative data. What is more, the criteria must use strong scales (such as ratio and interval ones), for which measuring distances according to the Minkowski formulas (6) and (7) may be applied only**. However, in the negotiation process some issues (criteria) may be described qualitatively or even verbally. For instance, in business negotiation the details of the warranty or returns may be such a complex issue that the full written returns policy (a few-pages-long text) is perceived as a resolution level. Negotiators are usually able to build a preorder for these resolution levels, indicating the best one (scored as 1), the second best (scored as 2), etc., but the distances between the numbers that reflect the order cannot be interpreted. Therefore another method for measuring distances for weak-scale data must be incorporated, if TOPSIS is going to be used for negotiation support.

2. TOPSIS and the problem of measuring distances for variables on ordinal scale

2.1. Generalized Distance Measure (GDM)

If the negotiation template was well discussed by negotiators in pre--negotiation phase and may be perceived as fixed and stable (no options are expected to be introduced later within the negotiation process) another approach for measuring distances between PIS and NIS may be applied. The notion of Generalized Distance Measure (GDM) may be used for calculating distances for different types of data. Generalized distance measure was proposed first

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* Other metrics are also proposed such as the Manhattan or Tchebycheff ones or even the weighted L_p metrics [see Jones and Mardle, 2004].

** Since addition and subtraction are mathematical operations that cannot be applied to the ordinal or nominal scales.

by Walesiak [2002]* who based his idea on the conception presented in a research book by Bock and Diday [2000]. GDM is based mainly on the notion of generalized correlation coefficient, which derives from Pearson linear correlation coefficient and Kendall tau rank correlation coefficient. GDM is given by the formula

$$d_{yz}^{GDM} = \frac{1}{2} - \frac{\sum_{k=1}^{n} w_k a_{yzk} b_{zyk} + \sum_{k=1}^{n} \sum_{\substack{j=1 \\ j \neq x,y}}^{m} w_k a_{yjk} b_{zjk}}{2\left[\sum_{k=1}^{n}\sum_{j=1}^{m} w_k a_{yjk}^{2} \cdot \sum_{k=1}^{n}\sum_{j=1}^{m} w_k b_{zjk}^{2}\right]^{\frac{1}{2}}}, \quad \text{for } j = 1, 2, \dots, m \tag{9}$$

where:

d_{yz}^{GDM} is a distance measure between objects (alternatives) A_y and A_z, $d_{yz}^{GDM} \in [0;1]$,

w_k is a weight of k-th variable (criterion): $w_k \in (0; m) \wedge \sum_{k=1}^{n} w_k = m$,

a_{yzk} and b_{zyk} are the distance indicators between objects (alternatives) A_y and A_z, for criterion k, and are calculated differently, depending on a type scale the criterion is measured with.

For ratio and interval variables the distance indicators are calculated intuitively using the following formulas

$$a_{y\alpha k} = x_{yk} - x_{\alpha k}, \quad \text{for } \alpha = z, j, \tag{10}$$

$$b_{z\beta k} = x_{zk} - x_{\beta k}, \quad \text{for } \beta = y, j. \tag{11}$$

For ordinal scale, for which the inequality statements for the objects compared (such as the state of being equal, grater or less than) may only be counted, Walesiak proposes to determine the distance indicator in the following way

$$a_{y\alpha k}(b_{z\beta k}) = \begin{cases} 1 \text{ for } x_{yk} > x_{\alpha k}\,(x_{zk} > x_{\beta k}) \\ 0 \text{ for } x_{yk} = x_{\alpha k}\,(x_{zk} = x_{\beta k}), \\ -1 \text{ for } x_{yk} < x_{\alpha k}\,(x_{zk} < x_{\beta k}) \end{cases} \tag{12}$$

for $\alpha = z, j$ and $\beta = y, j$.

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* GDM was described first by Walesiak [2002] originally in Polish. The detailed analysis of GDM and its properties was published later in English in the research paper by [Jajuga et al., 2003].

Walesiak proposes also the formulas for determining the distance indicators for the nominal scale variables. However, since we assumed that our negotiator is always able to define his general preferences for the qualitative issues by building a preorder of the options we will not use the nominal issues in the negotiation template.

Applying GDM to TOPSIS analysis requires two small changes in the general algorithm (Section 1). In the first step of the algorithm, the normalized matrix N should be computed for metric data only. Secondly, we omit step 2, since the variables will be weighted while calculating the GDM distance (formula (9)). Finally, in the step 4 while calculating d_j^+ and d_j^- the equations (6) and (7) need to be replaced with the GDM formula (9). Such modified TOPSIS algorithm we will call GDM-TOPSIS.

It is easy to conclude, while analyzing the above approach, that GDM--TOPSIS may be applied for negotiation support only if the template does not change within the negotiation process. It is a strong assumption, however, lots of negotiation support systems work with pre-defined fixed templates (such as Inspire [Kersten and Noronha, 1999], SmartSettle [Thiessen and Soberg, 2003]. The TOPSIS-GDM-based scoring system (offers' ranking) is built based on the distance comparisons between all feasible resolution levels that can be distinguished within the template* (see the second component of the addition formula in the numerator and the whole denominator of the equation (9)) therefore any future change in the sets of feasible resolution levels will affect the previous calculations and consequently the final ranking itself. In other words, to keep the scoring system determined by means of TOPSIS and GDM legitimate, only the offers comprised of the predefined (salient) options may be proposed during the negotiation process.

2.2. Alternative approach for weakly defined negotiation templates

Let us assume that the pre-negotiation talks did not lead negotiators to the formulation of a fixed negotiation template. Negotiators were able**, however, to find the negotiation space by defining the maximal and minimal acceptable values for quantitative issues but not for qualitative ones (e.g. returns policy). Each negotiator may have a few pre-defined options for this issue, but the smallest modification within this pre-defined contracts creates in fact another option. While making trade-off within this issue negotiators may create hundreds of versions of such a contract within the actual negotiation phase.

* It is based in fact on the pair-wise comparison of the offers.
** And usually are.

Therefore a special procedure needs to be introduced in the process of scoring the template (option evaluation), that will be insensible to new options that may appear later during the actual negotiation phase and the process of exchanging offers.

In this paper we propose to apply a very simple solution based on the pre--defined and ordered categories (clusters) of options*. We suggest to the negotiators to build the categories of options for each qualitative issue in pre--negotiation phase that will reflect the general quality of all feasible options that may appear in the negotiation process for this issue (e.g. the category of excellent options, the category of very good options, etc.). The number of the categories depends on the expected precision of the scoring system but should not be too big to avoid problems with assigning options to the pre-defined categories. This assignment process will be conducted by the negotiator himself, therefore he should define the optimal number of categories he is able to handle comfortably later on. By applying this approach we move from the verbally defined options (the set of which is not known at the beginning of the negotiation) to the numerically defined ones, while the numbers assigned to the categories are of the ordinal scale.

Since the weakly defined negotiation template (as described above) does not allow to build the set of feasible alternatives, some modifications need to be introduced into TOPSIS algorithm to remove all mathematical operations that require any information about this set of alternatives. First, the whole GDM distance formula needs to be changed, to avoid a calculation of some distance indicators that refer to the set of alternatives (i.e. the multipliers in the denominator of the equation (9)). We will change the Walesiak's formula (9), but we will still keep the general notion he used to build it. Walesiak used the Bock and Diday [2000] approach for measuring distance for ratio, interval, ordinal and nominal variables describes by formula

$$d_{yz} = \frac{w_1 d_{yz}^N + w_2 d_{yz}^O + w_3 d_{yz}^I + w_4 d_{yz}^R}{w_1 + w_2 + w_3 + w_4}, \tag{13}$$

where:

$N(O,I,R)$	is a subset of the nominal (ordinal, interval, ratio) variables under consideration,
$d_{yz}^{N(O,I,R)}$	is a distance calculated for the nominal (ordinal, interval, ratio) variables describing alternatives A_y and A_z,
$w_1(w_2, w_3, w_4)$	is a weight assigned to the nominal (ordinal, interval, ratio) variables.

* Similar categories-based approach for scoring the complete packages of offers by means of calibrated ELECTRE-TRI was previously proposed by Wachowicz [2010].

We will use the formula (13) for calculating the separation measures between alternatives and the PIS and NIS in the fourth step of TOPSIS removing the first component of the addition formula in the numerator of equation (13)*. Since the weights are taken into consideration during the distance aggregation, Step 2 of the original TOPSIS may be omitted here.

For measuring distances we will use the following formula

$$d_{yz}^{O(I,R)} = \frac{\left| x_{yk} - x_{zk} \right|}{v_k^+ - v_k^-}, \quad \text{for} \quad k = 1, \ldots, n\,. \tag{14}$$

where:

v_k^+, v_k^- are the maximal and maximal values defined by negotiators in weakly structured template for issue k.

Originally the measure (14) was proposed only for interval and ratio variables, but we will use the Kaufman and Rousseeuw [1990] rationale, according to which the formula (14) may be also used for ordinal variables. Some authors argue against Kaufman and Rousseeuw proposition, stating that the addition and subtraction are properties of interval and ratio scales only, but in our case – assuming that the negotiators build the option categories that differ by the same value of quality – the above formula may be applied. What is more, using the GDM for measuring the distances within the group of ordinal variables** will result in the same values of distances as the ones obtained with the formula (14). As we are using the formula (14) to calculate distances we do not need to normalize variables, therefore Step 1 of the classic TOPSIS procedure may be omitted.

Since all the above modifications were proposed for negotiation problem with weakly defined negotiation template we will call the whole modified TOPSIS procedure TOPSIS-WDT (TOPSIS-WeaklyDefinedTemplate).

3. Negotiation support for offers evaluation

Here we will summarize the notions presented in Section 3 and describe the procedure for negotiation support for the evaluation of negotiation offers. The procedure represents an asymmetric approach, i.e. it focuses on supporting only one party of the negotiation process. The structured algorithm of the supporting procedure is presented in Figure 1.

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* We assumed there are no ordinal variables in the negotiation template.

** It is legitimate since we previously assumed that negotiators pre-define the quality categories for these variables, so the set of options is known and fixed for this type of variables.

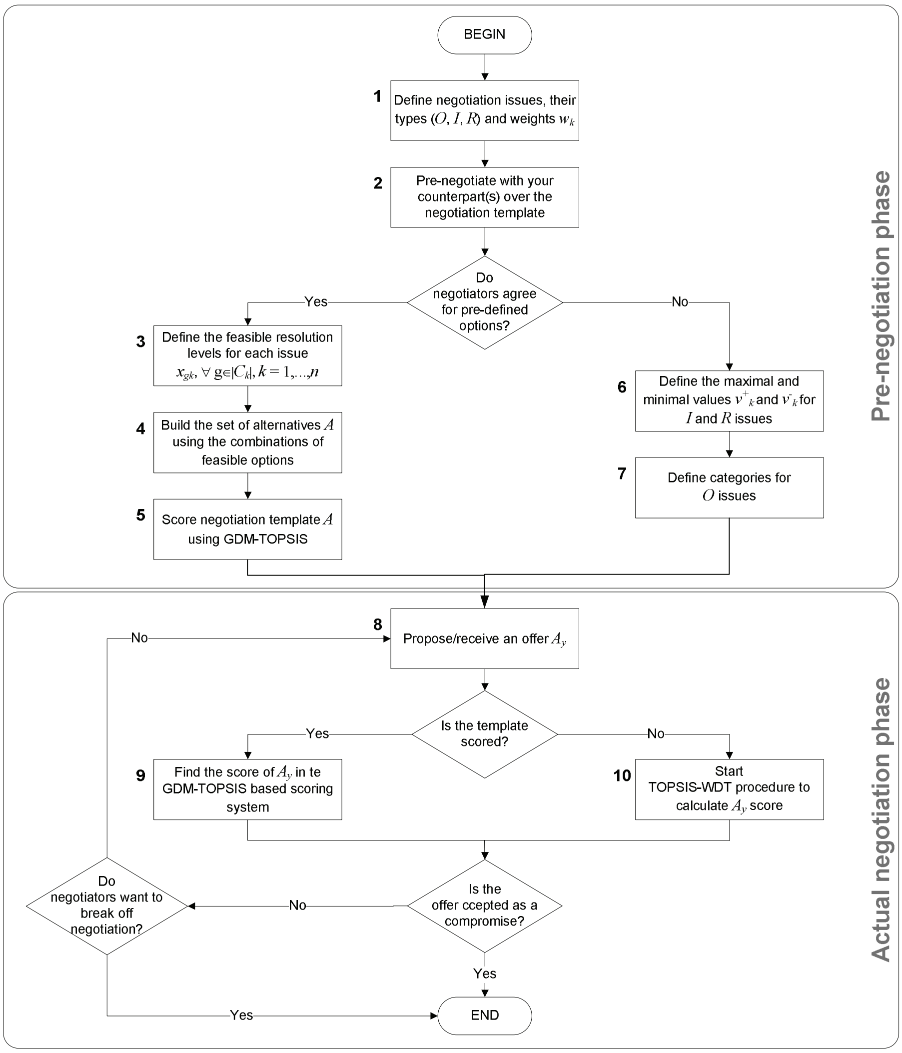

Figure 1. The algorithm for the evaluation of negotiation offers using TOPSIS

The template is defined in the pre-negotiation phase. Template definition begins with the identification of negotiation issues under consideration and the types of variables describing these issues (step 1). The individual, subjective importance of each issue should also be defined by the negotiator in this step in the form of weights. Next the pre-talks between negotiators are conducted to define the structure of the template (step 2). The aim of this step is to agree on the set of feasible resolution levels for each issue, which will remain stable during the negotiation process (no other options will be allowed). If negotiators agree on such pre-defined sets (which make the negotiation template fixed and the problem itself discrete), they specify these sets within step 3. When the sets of resolution level are agreed upon, the set of all feasible alternatives A is created* (step 4). The offers that comprise set A must take into consideration all possible combinations of feasible options defined within step 3. For the set A GDM-TOPSIS calculation procedure is run (step 5), which results in the construction of the negotiation offer scoring system, that may be used in pre-negotiation phase for simulation of the future negotiation process or later, in actual negotiation phase, to evaluate each offer proposed by the counterpart or to construct the negotiator's own proposal of agreement (step 9).

If the template was weakly defined (it is impossible to find the finite sets of feasible options for the issues), the negotiator defines the negotiation space only. In step 6 he sets the maximal and minimal acceptable values for each metric issue defining their feasible ranges. For ordinal issues he defines the categories and orders them from the most to the least preferred ones (step 7). The facilitator should assign numbers to the categories in descending order (i.e. the more preferred the category is the higher score it receives).

After the pre-negotiation actions, the actual negotiation support begins. It starts with the formulation of the offer by the negotiator or his counterparts (step 8). The negotiator now expects to have this offer evaluated. If he operates with fixed and well defined template, previously scored by the GDM-TOPSIS procedure he simply finds the offer proposed on the list of offers scored. He may compare it with the previous offers proposed within the negotiation process (or with his aspiration levels) and find other alternatives that will improve his score. If he operates with the weakly defined template he needs to start the TOPSIS-WDT procedure now and calculate the score of the offer proposed (step 10). The only reference points he has is the ideal offer PIS (of score 1) and the NIS (of score 0), so having the proposed offer scored he may analyze how close it is to PIS and NIS. If the offer is not satisfying he may try to build another one making an intuitive trade-off and score it running the TOPSIS--WDT procedure again. If he is satisfied with the score of the newly composed offer he may send it to his counterpart as an agreement suggestion. The steps 8, 9/10 are repeated until an agreement is set or negotiation is broken off.

The main difference between these two alternative paths in the algorithms is that for the weakly defined template (the right hand path of the algorithm) the offer evaluation process is conducted in the actual negotiation phase, just after the offer was proposed by negotiator. For well defined templates the scoring procedure is conducted in the pre-negotiation phase and later for

* It is a facilitator or negotiation support system task to prepare such a set for negotiators.

any offer proposed by the parties the scoring system is only browsed to find the score of this offer. Thus, when the template scored before the actual negotiation phase, the negotiator sees all the alternatives for agreement and at every stage (round) of negotiations he knows how far from the aspired level he is and what are the offers (complete packages) that may improve his current score. For the weakly defined template the negotiator may only score the current offer but he needs to construct a counteroffer by himself. What is more, this counteroffer will be scored after being constructed, so while building it he is not aware of the scale of concessions he is just making.

4. Example

4.1. GDM-TOPSIS application

Let us consider a simple business-to-business negotiation between a buyer (B) and a seller (S). They want to agree on the contract for new delivery of the components the buyer needs for production process. The negotiator S will be supported by the procedure proposed in the previous section of this paper*.

Step 1.

The negotiators want to agree on three different issues: price (Pr) per unit (in USD), time of delivery (TD) in days, and returns policy (RP). The first two issues are metric, while the last issue is ordinal. S has assigned the following weights to the issues: 0.6, 0.2, 0.2.

Step 2.

The negotiators agreed to prepare a fully defined negotiation template by defining no more than 6 salient options to for each negotiation issue.

Step 3.

The resolution levels defined by the negotiators for each issue are:

– for Pr: {3.60, 4.00, 4.20, 4.50},
– for TD: {30, 40, 60},
– for RP: {"any defects no penalty", "3% defects no penalty", "5% defects 2% penalty", "7% defects 4% penalty"}.

Since we assumed that the negotiators are able to build a preorder on resolution levels of any issue, B must define his preferences over the options of RP. The order (from the most to the least preferred) of the options with the ordinal scores assigned to them by a facilitator is presented in Table 1.

* The case is based on the assignment implied in electronic negotiation support Inspire.

Table 1

Ordinal scores for verbally defined options

	Options		
Order by negotiator	“any defects no penalty”	“3% defects no penalty”	“5% defects 2% penalty”, “7% defects 4% penalty”.
Scores by facilitator	3	2	1

Step 4.

The alternatives are built in the form of complete packages consisting of different combinations of options pre-defined in step 3. In our negotiation problem there is $4 \times 3 \times 4 = 48$ feasible offers that comprise the set A. One of such packages may be specified as $A_1 = (4.50, 60,$ “any defects no penalty”) while another as $A_{20} = (4.20, 40,$ “7% defects 4% penalty”). The full list of the offers is presented in Appendix 1, Table 2.

Step 5.

The set A is scored by means of GDM-TOPSIS procedure:
- RP options are replaced with their numerical equivalents (see Table 1),
- Pr and TD options are normalized using formula (2),
- PIS and NIS are defined: $A^+ = (4.50, 60, 3)$, $A^- = (3.60, 30, 1)$,
- separation measures d_j^+ and d_j^+ are calculated using formula (9) and distance indicators (10) and (11) for Pr and TD issues; and (12) for RP (see Appendix, Table 2),
- relative closeness S_j is calculated for each alternative (see Appendix, Table 2) and the ranking is built (see Appendix, Table 3)*.

Step 8.

An offer is send by B, $A_{26}^B = (4.00, 60,$ “3% defects no penalty”).

Step 9.

Since the negotiation template was well defined, S may now find the score of the offer A_{26}^B. He looks into ranking (Appendix, Table 3) and finds that $S_{26} = 0.63$. Having the template scored S also knows that there are two other offers that satisfy his preferences at the same level of 0.63:

* We used R language (ver. 2.11.0) and `pattern.GDM1()` and `pattern.GDM2()` procedures for determining the distance matrix in Appendix 2.

A_{11} = (4.50, 30, "5% defects 2% penalty"),

A_{12} = (4.50, 30, "7% defects 4% penalty").

If he is satisfied with this score but wishes to obtain a higher price, he may send a counteroffer to B choosing one of the above alternatives. If he expects the compromise to satisfy his preferences at the level no lower than 0.75* he may choose one of the first nine offers from the scored template (Appendix, Table 3).

Analyzing Table 3 (Appendix) he has also the insight into the values of the potential trade-off he may do. Let us assume that his offer A_5^S = (4.50, 40, "any defects no penalty") with the score $S_6 = 0.89$ was rejected by his counterpart and he may consider making small concession. If he decides to give in on TD (moving from 40 to 30 → from A_5 to A_9) his score will fall to the level of 0.78. If he decides to give in on RP (moving from "any defects no penalty" to "5% defects 2% penalty"→ from A_5 to A_6) his score will fall to the level of 0.85 only. Despite the fact that both issues TD and RP have the same weights it is more profitable for S to make a concession on RP, since it "costs" him less than the concession made on TD.

A similar analysis can be conducted in the next rounds of the negotiation process.

4.2. TOPSIS-WDT application

Let us now consider the same negotiation problem as described in Section 4.1, but for a weakly defined template. The steps 1 and 2 of the algorithm remain the same. The procedure now reaches the step 6.

Step 6.

Negotiator S defines the negotiation space by defining the maximal and minimal values for each metric issue: He sets:

– $v_{\mathrm{Pr}}^{+} = 4.50$ and $v_{\mathrm{Pr}}^{-} = 3.60$,

– $v_{TD}^{+} = 60$ and $v_{TD}^{-} = 30$.

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* Interpreted on the ratio scale as 75% of satisfaction or referring to offers being at least in 75% as good as the ideal one (PIS).

Step 7.

S defines categories for possible resolution levels of RP. Let us assume that he defines 3 categories of: good, average and weak options. The facilitator assigns the numerical equivalents to the categories: 3, 2, 1, respectively.

Step 8.

An offer is send by B, A^B = (4.00, 60, "3% defects no penalty").

Step 10.

TOPSIS-WDT calculation procedure is started by the facilitator or the negotiator himself. The score of A^B is equal to 0.56. S knows now that A^B is somewhere in the middle between the ideal and the negative ideal solutions. He does not have a scored template, so he can not find other solutions with the same score. If he would like to propose an offer giving him a score of 0.89 (as in previous case) he simply needs to try to improve the resolution levels of each issue intuitively and recalculate the score of the offer using the scoring system.

It is not a problem when NSS supports him and the calculations can be conducted automatically. Despite the fact that there is no well defined template for this negotiation NSS may find for S some equivalents of A^B lowering values of selected criteria and rising the values of others. NSS supports him similarly in making tradeoffs on the selected issues. If S's offer A^S = (4.50, 40, "any defects no penalty"), scored now with 0.87 points, is rejected, NSS may find another solution using a different combination of trade-off for declared concession level. Let us assume that S decided to make a concession of 0.05 scoring points. NSS finds for him such offers of 0.82 score*:

A_1 = (4.30; 53; "any defects no penalty"),

A_2 = (4.50; 48; "3% defects no penalty").

Conclusions

In this paper we have proposed two approaches for negotiation offer evaluation, both based on TOPSIS, as alternatives to the classic scoring systems widely used in negotiation support (such as additive scoring models or AHP-based scoring models). For a well structured template, where all feasible options are defined, GDM-TOPSIS procedure was proposed, whilst for a weakly

* These offers may be easily found by solving simple mathematic programming problem.

structure template, TOPSIS-WDT is suggested. Both procedures derive from the classic TOPSIS algorithm proposed by Hwang and Yoon [1981], but include some formal modifications that allow to analyze the negotiation problem for which ordinal issues were declared by negotiators.

The modified TOPSIS seems to be very effective in scoring a negotiation template. It does not require a tiresome interaction with negotiator to build a negotiation offer scoring system and releases him from an unintuitive assignment of scores to issues and options, but there are some drawbacks of the TOPSIS approach. Since it is based on distance measuring only, it does not take into account a nonlinearity of the negotiator's evaluation function. The negotiator may differently perceive the difference between the resolution levels of one issue, depending on how far these resolutions are from the ideal value of this issue. For instance, alternatives A and B may result in resolution levels 2000 and 1990 for issue x respectively (having the difference of 10 units) and the negotiator may perceive the difference between them as significant. Simultaneously, alternatives C and D may have the same difference of 10 points, but for the resolution levels 20 and 10, respectively. These two numbers may be perceived by the negotiator as equally bad, whilst TOPSIS will assign them different scores (distances) keeping the proportion of the differences for A, B and C, D at the same level. TOPSIS makes the differences between all options equally scored for any decision maker, as if the distance was the only objective measure of preferences. We are sure that there is a great number of scientists and researchers exploring the field of multiple attribute decision making that would not be willing to agree with this approach.

What should be noticed about the application of GDM in TOPSIS procedure, is the dependence of the distances between the ordinal options (their scores) on the number of these options. The distance is measured by the pair--wise comparisons between these options (see numerator in formula (9)). The greater number of options is worse than the hypothetical option o the greater "power" of option o is and the closer it is to the PIS. It is very important for scoring a well defined template, where the number of occurrences of an option for one particular ordinal issue depends on the number of options defined for other issues. The negotiator and facilitator should be aware of the potential problem that this may cause. For the same negotiation problem described by templates with different calibration of metric issues[*] different scorings may be obtained.

However, all the drawbacks presented above do not change the fact that scoring a negotiation template with TOPSIS is much quicker and less tiresome than using an additive scoring model or an AHP-based scoring model, since the only information we need from the negotiators are the weight coefficients

[*] E.g. in the first template the price issue will change of 10 cents (between 5 and 10 USD), while in the second it will change of 50 cents.

for the issues defined. Therefore the future work will focus on building a software tool for supporting negotiations according to GDM-TOPSIS and TOPSIS-WDT procedures, and comparing user satisfaction from using the classic scoring models and the TOPSIS-based ones.

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Appendix

Tabela 1

List of the feasible offers for B vs. S negotiations

Offer number	Issues		
	Pr	TD	RP
1	4.50	60	any defects no penalty
2	4.50	60	3% defects no penalty
3	4.50	60	5% defects 2% penalty
4	4.50	60	7% defects 4% penalty
5	4.50	40	any defects no penalty
6	4.50	40	3% defects no penalty
7	4.50	40	5% defects 2% penalty
8	4.50	40	7% defects 4% penalty
9	4.50	30	any defects no penalty
10	4.50	30	3% defects no penalty
11	4.50	30	5% defects 2% penalty
12	4.50	30	7% defects 4% penalty
13	4.20	60	any defects no penalty
14	4.20	60	3% defects no penalty
15	4.20	60	5% defects 2% penalty
16	4.20	60	7% defects 4% penalty
17	4.20	40	any defects no penalty
18	4.20	40	3% defects no penalty
19	4.20	40	5% defects 2% penalty
20	4.20	40	7% defects 4% penalty
21	4.20	30	any defects no penalty

Table 1 contd.

Offer number	Issues		
	Pr	TD	RP
22	4.20	30	3% defects no penalty
23	4.20	30	5% defects 2% penalty
24	4.20	30	7% defects 4% penalty
25	4.00	60	any defects no penalty
26	4.00	60	3% defects no penalty
27	4.00	60	5% defects 2% penalty
28	4.00	60	7% defects 4% penalty
29	4.00	40	any defects no penalty
30	4.00	40	3% defects no penalty
31	4.00	40	5% defects 2% penalty
32	4.00	40	7% defects 4% penalty
33	4.00	30	any defects no penalty
34	4.00	30	3% defects no penalty
35	4.00	30	5% defects 2% penalty
36	4.00	30	7% defects 4% penalty
37	3.60	60	any defects no penalty
38	3.60	60	3% defects no penalty
39	3.60	60	5% defects 2% penalty
40	3.60	60	7% defects 4% penalty
41	3.60	40	any defects no penalty
42	3.60	40	3% defects no penalty
43	3.60	40	5% defects 2% penalty
44	3.60	40	7% defects 4% penalty
45	3.60	30	any defects no penalty
46	3.60	30	3% defects no penalty
47	3.60	30	5% defects 2% penalty
48	3.60	30	7% defects 4% penalty

Tabela 2

Distance parameters for the offers

d_j^+	d_j^-	S_j
0.00	0.93	1.00
0.04	0.85	0.96
0.14	0.79	0.85
0.14	0.79	0.85
0.10	0.82	0.89
0.14	0.74	0.85
0.24	0.68	0.74
0.24	0.68	0.74
0.21	0.76	0.78
0.25	0.68	0.73
0.36	0.62	0.63
0.36	0.62	0.63
0.07	0.72	0.91
0.11	0.64	0.86
0.21	0.57	0.73
0.21	0.57	0.73
0.19	0.53	0.74
0.23	0.45	0.66
0.33	0.39	0.54
0.33	0.39	0.54
0.34	0.48	0.58
0.38	0.40	0.51
0.49	0.33	0.41
0.49	0.33	0.41
0.23	0.54	0.70
0.26	0.46	0.63
0.37	0.39	0.51
0.37	0.39	0.51
0.38	0.30	0.44
0.42	0.22	0.34
0.52	0.16	0.23
0.52	0.16	0.23
0.51	0.27	0.35
0.55	0.19	0.26
0.66	0.13	0.17
0.66	0.13	0.17

Table 2 contd.

d_j^+	d_j^-	S_j
0.58	0.33	0.37
0.61	0.25	0.29
0.72	0.19	0.21
0.72	0.19	0.21
0.72	0.17	0.19
0.76	0.09	0.10
0.87	0.02	0.03
0.87	0.02	0.03
0.79	0.14	0.15
0.83	0.06	0.07
0.93	0.00	0.00
0.93	0.00	0.00

Table 3

Negotiation offers' GDM-TOPSIS final ranking

Offer number	Issues			S_j
	Pr	TD	RP	
1	4.5	60	any defects no penalty	1.00
2	4.5	60	3% defects no penalty	0.96
13	4.2	60	any defects no penalty	0.91
5	4.5	40	any defects no penalty	0.89
14	4.2	60	3% defects no penalty	0.86
3	4.5	60	5% defects 2% penalty	0.85
4	4.5	60	7% defects 4% penalty	0.85
6	4.5	40	3% defects no penalty	0.85
9	4.5	30	any defects no penalty	0.78
7	4.5	40	5% defects 2% penalty	0.74
8	4.5	40	7% defects 4% penalty	0.74
17	4.2	40	any defects no penalty	0.74
10	4.5	30	3% defects no penalty	0.73
15	4.2	60	5% defects 2% penalty	0.73
16	4.2	60	7% defects 4% penalty	0.73
25	4	60	any defects no penalty	0.70
18	4.2	40	3% defects no penalty	0.66
11	4.5	30	5% defects 2% penalty	0.63
12	4.5	30	7% defects 4% penalty	0.63
26	4	60	3% defects no penalty	0.63
21	4.2	30	any defects no penalty	0.58
19	4.2	40	5% defects 2% penalty	0.54
20	4.2	40	7% defects 4% penalty	0.54

Table 3 contd.

Offer number	Issues			S_j
	Pr	TD	RP	
27	4	60	5% defects 2% penalty	0.51
28	4	60	7% defects 4% penalty	0.51
22	4.2	30	3% defects no penalty	0.51
29	4	40	any defects no penalty	0.44
23	4.2	30	5% defects 2% penalty	0.41
24	4.2	30	7% defects 4% penalty	0.41
37	3.6	60	any defects no penalty	0.37
33	4	30	any defects no penalty	0.35
30	4	40	3% defects no penalty	0.34
38	3.6	60	3% defects no penalty	0.29
34	4	30	3% defects no penalty	0.26
31	4	40	5% defects 2% penalty	0.23
32	4	40	7% defects 4% penalty	0.23
39	3.6	60	5% defects 2% penalty	0.21
40	3.6	60	7% defects 4% penalty	0.21
41	3.6	40	any defects no penalty	0.19
35	4	30	5% defects 2% penalty	0.17
36	4	30	7% defects 4% penalty	0.17
45	3.6	30	any defects no penalty	0.15
42	3.6	40	3% defects no penalty	0.10
46	3.6	30	3% defects no penalty	0.07
43	3.6	40	5% defects 2% penalty	0.03
44	3.6	40	7% defects 4% penalty	0.03
47	3.6	30	5% defects 2% penalty	0.00
48	3.6	30	7% defects 4% penalty	0.00

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