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A New Approach to Assessing the Biases of Decisions based on Multiple Attribute Decision making Methods

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Introduction

The emerging more sophisticated computer hardware and software provide the users with ample opportunity to use various computer-aided systems in various areas of activities. Enterprises and organizations pay special attention to the creation and development of information systems. The present paper focuses on the multiple attribute decision making methods, which are applying in the decision support and intelligent decision support systems.

Decision support and planning systems based on quantitative models have been developed and analysed in various countries for more than 50 years. A great number of multiple attribute decision making methods have been created in the world, however, we still do not know, which of them is most suited for solving a particular problem.

Decision support systems are created and used for solving various problems. Some IT specialists choose one particular decision making method as the basis of a decision support system, while others use several decision making methods. Deng and Santoso [1–12] describe a decision support system, aimed at evaluating IS projects based on multiple attribute analysis. This system uses multiple attribute decision making methods, including SAW, TOPSIS, AHP and ELECTRE.

The multiple attribute decision making methods are aimed at ranking the available alternatives. There are cases, when different methods give different results (i.e. the ranks of the same alternatives differ, depending on the methods used). This can be accounted for by differences in the basic principles of the considered methods.

Three popular multiple attribute decision making methods are analysed in the present work. They are TOPSIS - *Technique for Order Preference by Similarity to Ideal Solution* [5], SAW - *Simple Additive Weighting* [6] and COPRAS - *COmplex PRoportional Assessment* [12].

The decision making problems describing multidimensional situations may be solved by various multiple attribute decision making methods (MADM). Then, the question arises: which of these methods is the best and how to choose it [1, 7, 11].

According to Triantaphyllou [9], today, there is hardly any MADM method fully accepted by society or, at least, by most of the experts. The problem of determining the best MADM method should be treated as the MADM problem, requiring the best MADM method for its solution.

They performed the same analysis by comparing the methods WSM and TOPSIS. The analysis revealed that the method TOPSIS was not compared with the above methods.

Chen [3] performed the comparative analysis of SAW and TOPSIS, aimed at determining, which of these methods more effective in dealing with the data is presented as fuzzy values' intervals. The calculation of the correlations and the contradictions' rates allowed the author to assume that SAW is easier to understand and to apply to the analysis of fuzzy values.

There were some authors who considered the problem of decision reliability. For example, Pyy [8] offered to use the method DECREE (*DECision REliability Evaluation*) for probabilistic evaluation of decisions, when decision making is a sequence of significant events (e. g. accidents). The author applied the Bradley-Terry model to calculate the probability that the one alternative is better than the other alternative. The probability function and its definition were given by Birtolini [2].

Therefore, it may be stated that, actually, there are no methods of evaluating the reliability of MADM techniques. Taking this into consideration, the authors of the present paper offer a new approach to evaluate the reliability of the multiple attribute decisions by calculating the biases of results, which are made using the multiple attribute decision making methods. Four types of the decision biases are calculating: 1) the decision bias depending on the biases of the attribute values; 2) the decision bias depending on the attribute significance biases; 3) the joint bias of decision, depending on the biases of the attribute values and the attribute significance biases; 4) the bias of the method depending on the principles, underlying the particular methods used.

Formalization of a multiple attribute decision making problem

Suppose, that a decision-making problem is considered, whose solution is the selection of the optimal alternative with respect to the attribute values and significances. To solve this problem, the initial data, based on the number of alternatives *m* and the number of attributes *n,* are required. They are obtained as follows:

1. The number of the alternatives and attributes is determined, a set of alternatives $A=\{A_i\}$, $\left(i=\overline{1,m}\right)$ and a set of attributes $\left(X_1, X_2, \ldots, X_j, \ldots, X_n\right)$ are generated;
2. Based on the expert judgements, the estimates x_{ij}, indicates the performance of the considered alternatives A_i, when it is evaluated in terms of decision attribute X_j and their probable bias Δ_{ij} *(%)*, $\left(i=\overline{1,m}\right)$, $\left(j=\overline{1,n}\right)$ are entered. The table of decisions is constructed, based on these data;
3. A group of *P* experts, who will fill in the matrix of pairwise comparison of the attributes $P_k, \left(k=\overline{1,P}\right)$, is formed. Based on the filled in pairwise comparison matrices $P_k, \left(k=\overline{1,P}\right)$, the values of the subjective significance and the values of the integrated significance, which will be used in further calculations, are found [10];
4. The values of the integrated attribute significance, elicited from each expert, are presented as vectors: $q_k^* = \left(q_{1k}^*, q_{2k}^*, \ldots, q_{nk}^*\right)$, $\left(k=\overline{1,P}\right)$.

The new method for evaluating the biases of decision, and of the method

To evaluate the biases of a decision made with the help of multiple attribute decision making methods, when the biases of the initial data are given. The decision bias depending on the biases of the attribute values Δ_{ij}, $\left(i=\overline{1,m}\right)$, $\left(j=\overline{1,n}\right)$ is denoted by $\Delta_*^A(M)$; the decision bias depending on the attribute significance biases $\Delta_j^q, \left(j=\overline{1,n}\right)$ is denoted by $\Delta_*^B(M)$; the joint bias of decision, depending on the biases of the attribute values and the attribute significance biases is denoted by $\Delta^*(M)$.The total optimality bias $\Delta^*(M)$ of the alternative, which obtained the highest rank (one), is calculated for the variances of the results obtained by the applied method *M,* where $M \in \{TOPSIS, SAW, COPRAS\}$.

The application of the method of evaluating $\Delta^*(M)$ involves three stages: stage I – the calculation of the variances of the results obtained by the applied method *M* $S_A^2(M)$, depending on the biases of the attribute values Δ_{ij}, $\left(i=\overline{1,m}\right)$, $\left(j=\overline{1,n}\right)$; stage II – the calculation of the variances of the results obtained by the applied method *M* $S_B^2(M)$, depending on the attribute significance biases $\Delta_j^q, \left(j=\overline{1,n}\right)$; stage III – the calculation of the joint decision bias $\Delta^*(M)$ is based on the variances of the results $S_A^2(M)$, $S_B^2(M)$.

The actions of the stages I-II are performed by using the algorithm (Fig. 1).

The coefficients of variation, expressed as a percentage, given as the bias of efficiency values of the alternatives $\Delta_*^A(M)$ and $\Delta_*^B(M)$. These calculations are performed by using the algorithm (Fig. 1).

The actions of the stage III. In the light of the property of variance: if two variable X and Y are independent, the variance of their sum is given by $D(X+Y)=DX+DY$, then the standard deviation of variable *(X + Y)* is given by $S=\sqrt{D(X+Y)}$.

The coefficient variation (*cv*) is defined as the ratio of the standard deviation to the mean is given by: $cv=\frac{S}{\bar{x}}$

The coefficients of variation, expressed as a percentage, given as the bias of efficiency values of the most efficient alternative $cv_*(M)=\frac{\sqrt{S_{*A}^2(M)+S_{*B}^2(M)}}{\bar{x}_*}$, where $\bar{x}$ - is the mean of the efficiency estimates of the most efficient alternative given by stage I and stage II.

The bias of the method *M*, is denoted by Δ^M. The calculation of this bias consists of the three stages:

1. Using the decision matrixes $X_{[m\times n]}^k, \left(k=\overline{1,P}\right)$ and taking the vectors of the attributes' significance $q_k^* = \left(q_{1k}^*, q_{2k}^*, \ldots, q_{nk}^*\right)$, $\left(k=\overline{1,P}\right)$, the efficiency of the alternatives is calculated by applying each methods *M,* $M \in \{TOPSIS, SAW, COPRAS\}$. $P\times P$ variants of efficiency estimates of the alternatives are obtained $G^t(M)=\left(g_{1M}^t, g_{2M}^t, \ldots, g_{mM}^t\right), \left(t=\overline{1,P\times P}\right)$, by each method *M*, using the algorithm (Fig. 1);
2. Using data $G^t(M), \left(t=\overline{1,P\times P}\right)$, the mean efficiency values of each alternative $\overline{G}(M)=\left(\bar{g}_{1M}, \bar{g}_{2M}, \ldots, \bar{g}_{mM}\right)$ are calculated and the matrix $\mathbf{R}=\{r_{ij}\}, \left(i=\overline{1,m},\ j=\overline{1,Mt}\right)$ is composed, where *m* – is number of alternative, *Mt* – is number of methods, $\{r_{ij}\}$ - is the mean values of *i-th* alternative by applying *j-th* method;

3. The elements of matrix ***R*** are normalized using formula

$$\tilde{r}_{ij} = \frac{r_{ij}}{\sum_{i=1}^{m} r_{ij}}; \qquad (1)$$

4. A normalized matrix is denoted by $\tilde{R} = \{\tilde{r}_{ij}\}, \left(i = \overline{1,m},\ j = \overline{1,Mt}\right)$. The mean values $\bar{\tilde{r}}_j, \left(j = \overline{1,Mt}\right)$ of the rows' elements of the matrix $\tilde{R} = \{\tilde{r}_{ij}\}, \left(i = \overline{1,m},\ j = \overline{1,Mt}\right)$ are determined to be the real values of alternatives efficiency;
5. The biases of the methods for each alternative are calculated by the formula

$$\Delta_i^j = \left|\bar{\tilde{r}}_j - \tilde{r}_{ij}\right|, \left(i = \overline{1,m},\ j = \overline{1,Mt}\right). \qquad (2)$$

The authors for paper are offered to calculate the biases of the methods by the formula

$$\bar{\Delta}^j = \frac{1}{m}\sum_{i=1}^{m} \Delta_i^j, \left(j = \overline{1,Mt}\right). \qquad (3)$$

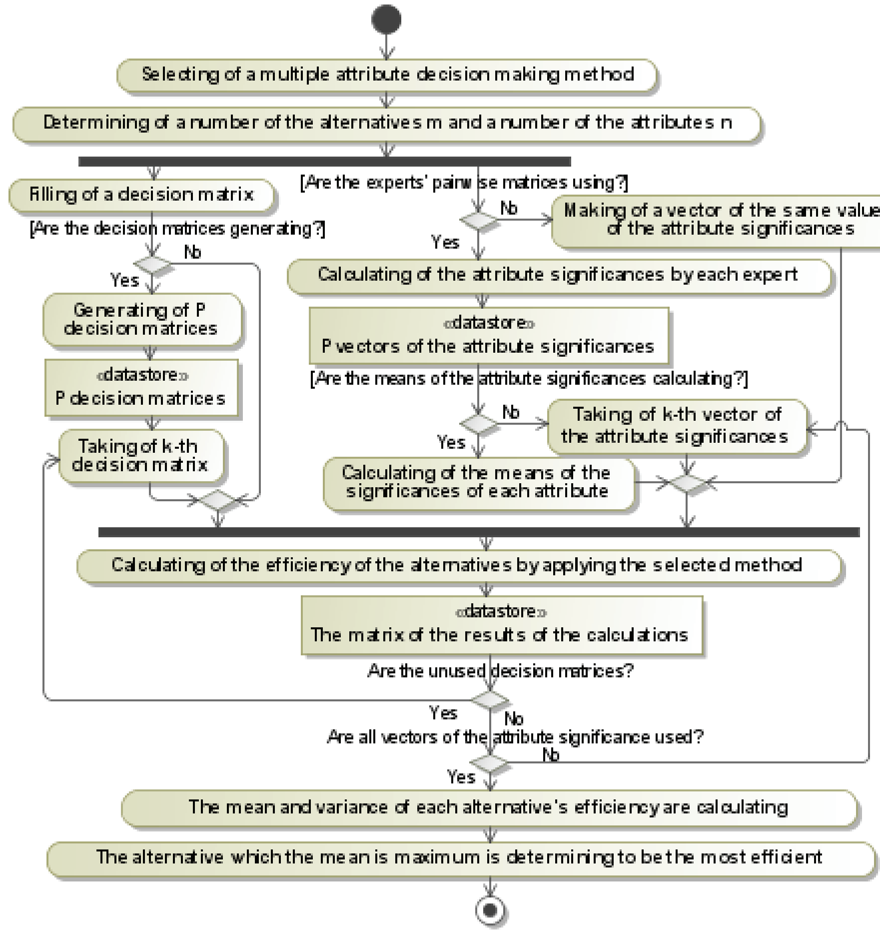

Fig. 1. The algorithm of the calculation of the decision biases depending on the initial data

Case study

A multiple attribute decision making problem, aimed at determining the best of three alternatives, evaluated based on four attributes, is stated. The values of the attributes are given in Table 1.

Table 1. Decision matrix

	X1	*X2*	*X3*	*X4*
A1	50	0,214	571	193
A2	78	0,213	665	299
A3	50	0,222	690	191
Max/min	Max	Min	Min	Min

A group of 13 experts, who helped to determine the attribute significance values, is formed.

Table 2. The biases of decisions

	TOPSIS-A1	**SAW-A1**	**COPRAS-A1**
$\Delta_*^A(M)$	0,123	0,026	0,017
$\Delta_*^B(M)$	0,034	0,002	0,002
$\Delta^*(M)$	10,2%	2,5%	1,8%
Δ^M	0,077	0,039	0,038

Based on the assumption that the biases of the attribute values are equal to 5% and following the normal distribution, 13 decision matrixes were generated. According to the methods TOPSIS, SAW and COPRAS, the best alternative was A_1. The real efficiency value of alternative A_1 is 0,455.

Using the proposed method for the calculation of the decision biases, the values of the biases are given (Table 2).

According to the method TOPSIS, the total efficiency bias of this alternative reaches 10,2%, while that obtained by using the method SAW is 2,5%, the method COPRAS – 1,8%. Based on the obtained decision biases, it is concluded that the decision yielded by COPRAS has the smallest bias and is more reliable (efficient) than the decision obtained by the method TOPSIS or the method SAW.

Conclusions and further research

The analysis of the related works performed by the authors has shown that, actually, there are no methods of determining the reliability of decisions obtained by using multiple attribute decision making methods with respect to probable biases of the initial data and the principles of the methods used. The present work offers a new approach to evaluating the decision biases, when MADM methods are used. It takes into account the values and significances of the attributes and major principles of a particular MADM method.

The suggested approach may be used, when MADM methods are applied. Further research will focus on the analysis of multiple attribute decision making methods from various perspectives.

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The emerging more sophisticated computer hardware and software provide the users in various areas of activities with ample opportunity to use various computer-aided systems. One type of these systems includes decision support systems based on the use of multiple attribute decision making methods. In designing such systems, the question arises, which of MADM methods is more efficient and should be used in evaluating taking into account that the best alternatives yielded by these methods often differ. A great number of researchers are trying to answer these and other similar questions. However, they usually arrive at the same conclusion that the considered methods are based on different principles, but the best (or most efficient) MADM method can hardly be found. Therefore, the authors of the present paper offer a method of evaluating the reliability of decisions, obtained by using MADM methods and their biases, taking into account the biases of the initial data pertaining to the problem solved and basic principles of various multiple attribute decision making methods applied. Ill. 1, bibl. 12, tabl. 2 (in English; abstracts in English and Lithuanian).

R. Simanavičienė, L. Ustinovičius. Naujas daugiatikslių sprendimų paklaidų skaičiavimo metodas // Elektronika ir elektrotechnika. – Kaunas: Technologija, 2012. – Nr. 1(117). – P. 29–32.

Tobulėjanti kompiuterinė technika bei programinė įranga, suteikia daugiau galimybių vartotojui daugelyje veikos sričių naudoti įvairias kompiuterines sistemas. Vienas iš tokių sistemų tipų – sprendimo paramos sistemos, naudojančios daugiakriterius sprendimo priėmimo metodus. Projektuojant tokias sistemas, iškyla klausimų: kurį daugiakriterį sprendimo priėmimo metodą taikyti sistemoje, atsižvelgiant į tai, jog kartais atskirų metodų rezultatai dėl optimalios alternatyvos nesutampa?, kuris sprendimo priėmimo metodas yra geresnis? Į šiuos ir panašius klausimus bando atsakyti daugelis mokslininkų, bet dažniausiai prieina prie vienos išvados: kiekvienas metodas turi savų prielaidų, o geriausio metodo nėra, todėl šiame darbe autoriai siūlo metodą, kurį taikant būtų galima įvertinti daugiakriterio sprendimo patikimumą skaičiuojant rezultato paklaidas uždavinio pradinių duomenų ir taikomų daugiatikslių sprendimo priėmimo metodų prielaidų atžvilgiu. Il. 1, bibl. 12, lent. 2 (anglų kalba; santraukos anglų ir lietuvių k.).