A Modified Weighted Sum Method Based on the Decision-maker's Preferred Levels of Performances

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Abstract: This paper proposes a modified version of the Weighted Sum method that takes into account decision-maker preferences and provides a possibility of higher interactivity in the selection of the most suitable alternative. The proposed approach uses a specific normalization procedure, which takes into account decision-maker preferences and also introduces a compensation coefficient that enables the decision-maker to make choices between alternatives with higher overall performance ratings and alternatives that better match the decision-maker preferences.

Keywords: MCDM, Multiple Criteria Decision Making, preferred performance ratings, Weighted Sum Method, normalization procedures, ideal point approach

1. Introduction

Multiple Criteria Decision Making (MCDM) is one of the most important and the fastest growing subfields of the management science. As a result of its rapid development, many MCDM methods have also been proposed, such as: SAW [1, 2] or WS [3], AHP [4], TOPSIS [5], PROMETHEE [6], ELECTRE [7], COPRAS [8] and VIKOR [9].

In order to ensure their usage for solving various complex decision-making problems, these methods are often adapted or extended to apply fuzzy or grey numbers. For example, the ELECTRE method has several variants, namely ELECTRE I, ELECTRE II, ELECTRE III, ELECTRE TRE and ELCTRE IV [10, 11].

In addition, the introduction and the usage of new MCDM methods, such as ARAS [12], MULTIMOORA [13] and WASPAS [14, 15], as well as their extensions, are also noticeable.

The proposed MCDM methods are used to solve a wide variety of decision-making problems, such as: evaluation of environmental impact [16], selecting software and hardware infrastructure for cyber security centre [17], evaluating performances of a fish farm [18], selecting a contractor [15, 19].

A great number of papers considered the use of different MCDM methods for solving decision-making problems, such as [19, 20, 21].

The Weighted Sum (WS) method, more often referred to as the Simple Additive Weighted (SAW) method, is probably the best-known and the earlier, widely used, MADM method [5, 14].

Although the use of the WS method is significantly substituted by other MCMD methods, it is still topical, as has been evidenced in some recent researches, such as the following ones: Chou *et all*. [22] used the fuzzy SAW for solving the facility location selection problem; Zavadskas *et al*. [19] applied grey extensions of the SAW and the TOPSIS methods for solving the contractor selection problem; Rădulescu and Rahoveanu [18] used framework based on SAW and AHP method for evaluating performances of a fish farm; Cheng [23] conducted a comparative study about the use of interval-valued fuzzy extensions of the SAW and the TOPSIS methods and noticed that significant similarities existed between the interval-valued fuzzy SAW and TOPSIS rankings; Rikhtegar *et al*. [19] used fuzzy SAW to evaluate environmental impacts of construction projects; Dogan *et al*. [24] combined the SAW method and a mixture design to determine the optimum cocoa combination of hot chocolate beverage; Wang [25] applied a fuzzy extension of the SAW method for solving the distribution centre location selection problem, and Stejskal *et al*. [26] used the WS method to evaluate the effects arising from the existence of the regional innovation system of the regions of the Czech Republic.

Based on the WS method and the new normalization procedure, Stanujkic *et al*. [27] suggested an approach that to a greater extent takes into account decision-maker preferences. In the above mentioned approach for each criterion, target levels of performances, called preferred performance ratings, were introduced. The aim of the decision maker is to obtain a range of alternatives that takes into account the preferred performance ratings.

In this paper, this approach is further improved, thus providing decision-makers with a possibility of higher interactivity in the selection of the most suitable alternative. The rest of this paper is, therefore, structured as follows: In Section 2 of the paper, the Weighted Sum method is presented, while in Section 3, the normalization procedure based on distances from decision-maker's preferences is considered. Section 4 proposes a new approach. An illustrative example is discussed, with the aim to explain the proposed approach, in Section 5. Finally, the conclusions are given.

2. The Weighted Sum Method

As previously stated, the WS method is one of the best-known and the simplest MCDM methods. The basic idea of the WS method is to calculate the overall performance rating of an alternative *i* as a sum of products of normalized performance ratings and weights of criteria, as follows [2, 28]:

$$S_i = \sum_{j=1}^{n} w_j \cdot r_{ij} , \qquad (1)$$

where S_i denotes the overall performance rating of the alternative *i*, w_j is the weight of the criterion *j*, r_{ij} is the normalized performance rating of the alternative *i* with respect to the criterion *j*, and $S_i \in [0,1]$.

The WS method can be used with different normalization procedures, such as: Vector Normalization or Max and Max-Min Linear Normalizations. A comprehensive overview of the normalization procedures is given in Zavadskas and Turskis [29], and Celen [30], whereas the use of the WS method with different normalization procedures is discussed in Chakraborty and Yeh [31], and Stanujkic *et al*. [32].

3. Normalization Based on Distances from Decision-Maker Preferences

Based on Weitendorf [33] and Juttler [34], Stanujkic *et al*. [27] suggested a normalization procedure allowing decision-makers to more appropriately express their preferences about preferred performance ratings, for some or all evaluation criteria, as follows:

$$r_{ij} = \frac{x_{ij} - x_j^*}{x_j^+ - x_j^-} ; \; j \in \Omega_{\max} , \text{ and} \qquad (2)$$

$$r_{ij} = \frac{x_j^* - x_{ij}}{x_j^+ - x_j^-} ; \; j \in \Omega_{\min} \qquad (3)$$

where x_j^* denotes the preferred performance rating of the criterion *j*, x_{ij} denotes the performance rating of the alternative *i* with respect to the criterion *j*, x_j^+ and x_j^- denotes the largest and the smallest performance rating of the criterion *j*, respectively, $\Omega_{\max}$ and $\Omega_{\min}$ are the set of the benefit criteria (maximization criteria) and the cost criteria (minimization criteria), respectively.

As the result of the use of this normalization procedure, Eq. (1) can be written as follows

$$S_i = S_i^+ + S_i^- , \qquad (4)$$

where:

$$S_i^+ = \sum\nolimits_{r_{ij}>0} w_j r_{ij} , \qquad (5)$$

$$S_i^- = \sum\nolimits_{r_{ij}<0} w_j r_{ij} , \text{ and} \qquad (6)$$

S_i^+ and S_i^- denote the performance ratings of the alternative *i*, obtained on the basis of the criteria satisfying the condition $r_{ij}>0$, or the condition $r_{ij}<0$, respectively; d_{ij} denotes the weighted normalized distance of the alternative *i* to the preferred performance ratings obtained on the basis of the criterion *j*, and $S_i \in [-1,1]$.

Using this approach, the overall performance ratings of the alternatives that have performance ratings equal to the preferred performance ratings are equal to zero, i.e. $S_i = 0$. The alternatives whose one or more preference ratings are better than preferred performance ratings, $\sum\nolimits_{r_{ij}>0} w_j r_{ij} > 0$, or the alternatives whose better performance ratings successfully compensate for the impact of worse performance ratings, $\sum_{r_{ij}>0} w_j r_{ij} + \sum_{r_{ij}<0} w_j r_{ij} > 0$, have $S_i > 0$.

From the above-mentioned, it is clear that:

- the alternatives whose values of S_i are larger than or equal to zero, $S_i \geq 0$, are more preferable compared to the alternatives whose values of S_i are smaller than zero, i.e. $S_i < 0$;
- the value of S_i depends on the number of the criteria whose performance ratings deviate from the preferred performance ratings, as well as the levels (distances) and directions of deviations;
- an increase in a deviation from the preferred performance ratings in the desired direction results in an increase in S_i.

4. The Proposed Approach for Ranking Alternatives, Based on Preferred Performance Ratings

Using the WS method and the normalization procedure proposed by Stanjkic *et al.* [27], i.e. using Equationss (1), (2) and (3), the most appropriate alternative is the one that has the highest S_i. At the same time, the alternatives whose S_i is higher than 0 make a set of the most acceptable alternatives.

In this approach, however, high values for S_i of highly-placed alternatives can sometimes be obtained on the basis of a greater distance of only one criterion or a few criteria.

Therefore, in order to further improve the above approach, under the name the **W**eighted **S**um adapted for an analysis based on decision-maker **P**referred **L**evels of **P**erformances (WS PLP), the use of a compensation coefficient is proposed in this paper, as follows:

$$S_i' = \sum_{j=1}^{n} w_j r_{ij} - \gamma c_i, \tag{7}$$

where S_i' denotes the adjusted overall performance rating of the alternative i, c_i is the compensation coefficient; $c_i > 0$, γ is the coefficient; $\gamma = [0,1]$.

The compensation coefficient should provide adequate ratios, or to be more precise, such ones acceptable for a decision-maker, ranging between the greatest possible value of S_i and a better matching with the preferred performance ratings; it should be calculated as follows:

$$c_i = \lambda d_i^{\max} + (1-\lambda) \bar{S}_i^+, \tag{8}$$

where:

$$d_i^{\max} = \max_i d_i = \max_i r_{ij} w_j, \tag{9}$$

$$\bar{S}_i^+ = \frac{S_i^+}{n_i^+}, \text{ and} \tag{10}$$

$d_i^{\max}$ denotes the maximum weighted normalized distance of the alternative i against the preferred performance ratings of all the criteria so that $r_{ij} > 0$, $\bar{S}_i^+$ denotes the average performance ratings achieved on the basis of the criteria so that that $r_{ij} > 0$, n_i^+ denotes the number of the criteria of the alternative i so that $r_{ij} > 0$, λ is coefficients; $\lambda = [0,1]$ and is usually set at 0.5 .

The compensation coefficient has higher values for alternatives whose higher values of S_i^+ are obtained on the basis of greater distances from the preferred performance ratings, in which way it reduces the values of the S_i' of such alternatives. In this way, it fine-tunes the ranking order of the considered alternatives. By varying the values of λ, a decision-maker can assign a different significance to $d_i^{\max}$ and $\bar{S}_i^+$, while by varying γ, he or she can assign a different significance to c_i.

The use of and the influence of c_i on S_i', i.e. the impact on the selection of the alternative that to a great extent meets decision-maker preferences, are examined in detail in Appendix A.

4.1. The computational procedure of the proposed approach

Based on the above considerations, the calculation procedure of the proposed WS PLP approach can precisely be expressed by using the following steps:

Step 1. **Create a decision matrix and determine the weights of the criteria**.

The process of selecting the most appropriate alternative using the WS PLP approach, similarly to other MCDM methods, begins with the formation of a decision matrix and the determination of the weights of the criteria.

Step 2. **Define the preferred performance ratings for each criterion**.

After having created the initial decision matrix, the first step in the proposed approach is the forming of the virtual alternative $A_0 = \{x_{01}, x_{02}, \ldots, x_{0n}\}$, whose elements are the preferred performance assigned by the decision-maker's preferences. If the preferred performance rating of any criterion is not assigned, it is determined as follows:

$$x_{0j} = \begin{cases} \max\limits_i x_{ij} & | \; j \in \Omega_{\max} \\ \min\limits_i x_{ij} & | \; j \in \Omega_{\min} \end{cases}, \tag{11}$$

where x_{0j} denotes the optimal performance rating of the criterion j.

Step 3. **Construct a normalized decision matrix**.

In the proposed approach, normalized performance ratings should be calculated as follows:

$$r_{ij} = \frac{x_{ij} - x_{0j}}{x_j^+ - x_j^-}, \tag{12}$$

where:

$$x_j^+ = \begin{cases} \max\limits_i x_{ij} & | \; j \in \Omega_{\max} \\ \min\limits_i x_{ij} & | \; j \in \Omega_{\max} \end{cases}, \text{ and} \tag{13}$$

$$x_j^- = \begin{cases} \min\limits_i x_{ij} & | \; j \in \Omega_{\max} \\ \max\limits_i x_{ij} & | \; j \in \Omega_{\max} \end{cases}. \tag{14}$$

In the proposed approach Equations (2) and (3), proposed by Stanujkic *et al*. [27], are replaced with Equations (12).

Step 4. **Calculate the overall performance rating for each alternative**.

Overall performance ratings should be calculated using Equation (1).

If there are two or more alternatives whose $S_i > 0$, the calculation procedure continues through the following steps. Otherwise, the alternatives are ranked in ascending order and the alternative with the largest S_i is the most acceptable one.

Step 5. **Calculate the compensation coefficient.**

Calculate the compensation coefficient for all alternatives with $S_i > 0$. The compensation coefficient should be calculated using Equation (8).

Step 6. **Calculate the adjusted performance rating.**

Calculate the adjusted performance rating, for all alternatives with $S_i > 0$. Adjusted performance ratings should be calculated using Equation (7), where a decision-maker can reduce, or even totally eliminate, the impact of the compensation coefficient by varying the values of the coefficient γ.

Step 7. **Rank the alternatives and select the most efficient one**.

The considered alternatives are ranked by ascending S_i' and the alternative with the largest value of S_i' is the most appropriate one.

5. A Numerical Example

In this section, a numerical example of purchasing an office building, borrowed from [21], and slightly modified, is considered in order to explain the proposed approach in detail.

The selected criteria, the criteria weights, the optimization directions, the performance ratings of the four alternatives and the preferred performance ratings (ppr) are shown in Table 1.

Table 1. The initial decision matrix

	Price (10,000 \$)	**Office area (m^2)**	**Distance from the city center (km)**	**Office location quality (in points)**
	C_1	C_2	C_3	C_4
Optimization	min	max	min	max
w_j	0.095	0.230	0.193	0.481
ppr	2.2	80	12	7
A_1	3.0	100	10	7
A_2	2.5	80	8	5
A_3	1.8	50	20	11
A_4	2.2	70	12	9

The normalized performance ratings, calculated by using Equations (2) and (3), are accounted for in Table 2.

Table 2. The normalized performance ratings

	C_1	C_2	C_3	C_4
A_1	-0.67	0.40	0.17	0.00
A_2	-0.25	0.00	0.33	-0.33
A_3	0.33	-0.60	-0.67	0.67
A_4	0.00	-0.20	0.00	0.33

The overall performance ratings of the considered alternatives, obtained by using Equation (1), are presented in Table 3.

Table 3. The ranking results obtained on the basis of S_i

	S_i	Rank
A_1	0.06	3
A_2	-0.12	4
A_3	0.09	2
A_4	0.11	1

As can be seen from Table 3, the alternative A_4 is the best-placed alternative, whereas the alternatives A_4, A_3 and A_1 make a set of the most acceptable ones.

The adjusted overall performance rating of the alternatives, for γ=1 and λ =0.5, are shown in Table 4.

The high value of the S_i of the alternative A_4 is achieved on the basis of a higher deviation from the preferred performance rating of the criterion C_4. In contrast to this, the alternative A_1 its slightly lower value of S_i is achieved on the basis of the deviations from the preferred performance ratings of the criteria C_2 and C_3.

Because of this, the alternative A_4 has a lower value of the compensation coefficient, which causes it to become the highest-ranked alternative by using the WS PLP approach and the high value of the coefficient γ.

The influence of the compensation coefficient on the selection of the most acceptable alternative for several characteristic values of the coefficient γ is demonstrated in Table 5 and in Figure 1.

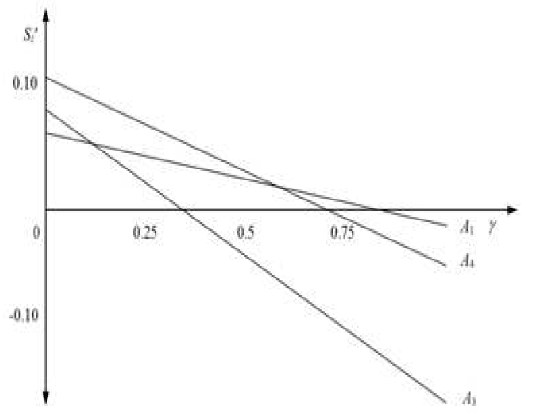

Figure 1. The influence of the coefficient γon the adjusted overall performance rating

Table 4. The ranking results obtained on the basis of S_i'

	$d_i^{\max}$	S_i^+	n_i^+	$\bar{S}_i^+$	c_i	S_i	S_i'	Rank
A_1	0.09	0.12	2	0.06	0.08	0.06	-0.02	1
A_3	0.32	0.35	2	0.18	0.25	0.09	-0.16	3
A_4	0.16	0.16	1	0.16	0.16	0.11	-0.05	2

Table 5. The ranking results obtained on the basis of the different values of γ

	γ= 0		γ= 0.5			γ= 1		
	S_i'	Rank	c_i	S_i'	Rank	c_i	S_i'	Rank
A_1	0.06	3	0.039	0.02	2	0.08	-0.02	1
A_3	0.09	2	0.124	-0.04	3	0.25	-0.16	3
A_4	0.11	1	0.080	0.03	1	0.16	-0.05	2

6. Conclusion

In this paper, an approach that takes into account decision-maker preferences, or more precisely decision-maker preferred performance ratings, and enables decision-maker higher interaction in the selection process, or to be more precise enables them to make choice between higher overall performance ratings and a better matching with the decision-maker's preferences, is presented.

The proposed approach is based on the use of the Weighted Sum method and the Normalization Procedure that takes into account decision-maker preferred performance ratings. Using this approach, the alternatives with one or more preference ratings better than the preferred performance ratings could compensate for the impact of their worse performance ratings obtained in relation to the remaining criteria.

By introducing the compensation coefficient, decision-makers come to a possibility of making their choice between higher overall performances and a better matching with preferred performances, thus making a selection of the most appropriate alternative out of a set of the most appropriate alternatives or, in other words, select the alternative that to a great extent meets the decision-maker's preferences.

In addition, the normalization procedure used in the proposed approach slightly shifted the Weighted Sum method from the scoring-based to the distance-based approaches, i.e. the ideal-point approaches.

Finally, the usability of the proposed approach has been discussed and confirmed on an example of the location selection problem.

References

1. CHURCHMAN, C.W., R. L. ACKOFF, **An Approximate Measure of Value**, Journal of the Operations Research Society of America, vol. 2, no. 2, 1954, pp. 172-187.
2. MacCRIMON, K. R., **Decision Marking Among Multiple-Attribute Alternatives: a Survey and Consolidated Approach**, RAND memorandum, RM-4823-ARPA, 1968.
3. FISHBURN, P. C., **Additive Utilities with Incomplete Product Set: Applications to Priorities and Assignments**, Operations Research, vol. 15 no. 3, 1967, pp. 537-542.
4. SAATY, T. L., **The Analytic Hierarchy Process: Planning, Priority Setting, Resource Allocation**. New York: McGraw-Hill, 1980.
5. HWANG, C. L., K YOON, **Multiple Attribute Decision Making - Methods and Applications**, Springer, New York, 1981.
6. BRANS, J. P., P. VINCKE, **A Preference Ranking Organization Method: The PROMETHEE Method for MCDM**, Management Science, vol. 31, no. 6, 1985, pp. 647-656.
7. ROY, B. **The Outranking Approach and the Foundation of ELECTRE Methods, Theory and Decision**, vol. 31, no. 1, 1991, pp. 49-73.
8. ZAVADSKAS, E. K., A. KAKLAUSKAS, V. SARKA, **The New Method of Multicriteria Complex Proportional Assessment of Projects**, Technological and Economic Development of Economy, vol. 1, no. 3, 1994, pp. 131-139.
9. OPRICOVIC, S. **Multicriteria Optimization of Civil Engineering Systems**, Faculty of Civil Engineering, Belgrade, 1998. (In Serbian)
10. HERSH, M., **Mathematical Modelling for Sustainable Development,** Springer Science & Business Media, Springer-Verlag Berlin Heidelberg, 2006, pp. 557
11. TAM, C. M., K. L. THOMAS, H. ZHANG, **Decision Making and Operations Research Techniques for Construction Management**, City University of HK Press, 2007, pp. 328.
12. ZAVADSKAS, E. K., Z. TURSKIS, **A New Additive Ratio Assessment (ARAS) Method in Multicriteria Decision-Making**, Technological and Economic Development of Economy, vol. 16, no 2, 2010, pp. 159-172.
13. BRAUERS, W. K. M., E. K. ZAVADSKAS, **Project Management by MULTIMOORA as an Instrument for Transition Economies**, Technological and

Economic Development of Economy, vol. 16, no. 1, 2010, pp. 5-24.

14. ZAVADSKAS, E. K., Z. TURSKIS, J. ANTUCHEVICIENE, A. ZAKAREVICIUS, **Optimization of Weighted Aggregated Sum Product Assessment**, Elektronika ir elektrotechnika, vol. 122(6), 2012, pp. 3-6.
15. ZAVADSKAS, E. K., Z. TURSKIS, J. ANTUCHEVICIENE, **Selecting a Contractor by Using a Novel Method for Multiple Attribute Analysis: Weighted Aggregated Sum Product Assessment with Grey Values (WASPAS-G)**, Studies in Informatics and Control, vol. 24, no 2, 2015, pp. 141-150.
16. RIKHTEGAR, N., N. MANSOURI, A. AHADI OROUMIEH, A. YAZDANI-CHAMZINI, E. KAZIMIERAS ZAVADSKAS, S. KILDIENĖ, **Environmental Impact Assessment based on Group Decision-making Methods in Mining Projects**, Economic Research - Ekonomska Istraživanja, vol 27, no 1, 2014, pp. 378-392.
17. RESTEANU, C., E. MITAN, M. ANDREICA, G. PACURAR, **Optimal Infrastructure for Acquiring and Processing of Data Related to Anthropic Computer Incidents**, Studies in Informatics and Control, vol. 24, no 1, 2015, pp. 51-60.
18. RĂDULESCU, C. Z., M. T. RAHOVEANU, **A Multi-criteria Evaluation Framework for Fish Farms**, Studies in Informatics and Control, vol. 20, no. 2, 2011, pp.181-186.
19. ZAVADSKAS, E. K., T. VILUTIENE, Z. TURSKIS, J. TAMOSAITIENE, **Contractor Selection for Construction Works by Applying SAW-G and TOPSIS Grey Techniques**, Journal of Business Economics and Management, vol. 11, no. 1, 2010, pp. 34-55.
20. ZAVADSKAS, E. K., Z. TURSKIS, R. VOLVAČIOVAS, S. KILDIENE, **Multi-criteria Assessment Model of Technologies**, Studies in Informatics and Control, vol. 22, no 4, 2013, pp. 249-258.
21. USTINOVICHIUS, L., E. K. ZAVADSKAS, V. PODVEZKO, **Application of a Quantitative Multiple Criteria Decision Making (MCDM-1) Approach to the Analysis of Investments in Construction**, Control and Cybernetics, vol. 36, no. 1, 2007, pp. 251-268.
22. CHOU, S. Y., Y. H. CHANG, C. Y. SHEN, **A Fuzzy Simple Additive Weighting System under Group Decision-making for Facility Location Selection with Objective/Subjective Attributes**, European Journal of Operational Research, vol. 189, no. 1, 2008, pp. 132-145.
23. CHEN, T. Y., **Comparative Analysis of SAW and TOPSIS based on Interval-valued Fuzzy Sets: Discussions on Score Functions and Weight Constraints**, Expert Systems with Applications, vol. 39, no. 2, 2012, pp. 1848-1861.
24. DOGAN, M., T. AKTAR, O. S. TOKER, N. B. TATLISU, **Combination of the Simple Additive (SAW) Approach and Mixture Design to Determine Optimum Cocoa Combination of the Hot Chocolate Beverage**, Intl. J. of Food Properties, vol. 18(8), 2015, pp. 1677-1692.
25. WANG, Y. J., **A Fuzzy Multi-criteria Decision-making Model based on Simple Additive Weighting Method and Relative Preference Relation**, Applied Soft Computing, vol. 30, 2015, pp. 412-420.
26. STEJSKAL, J., K. NEKOLOVA, A. ROUAG, **The Use of the Weighted Sum Method to Determine the Level of Development in Regional Innovation Systems-using Czech Regions as Examples 1**, Economicky Casopis, vol. 63, no. 3, 2015, pp. 239-258.
27. STANUJKIC, D., N. MAGDALINOVIC, R. JOVANOVIC, **A Multi-Attribute Decision Making Model Based on Distance from Decision Maker's Preferences**, Informatica, vol. 24 no. 1, 2013, pp. 103-118.
28. TRIANTAPHYLLOU, E., S. H. MANN, **An Examination of the Effectiveness of Multi-dimensional Decision-making Methods: A Decision-making Maradox**, Decision Support Systems, vol. 5, no. 3, 1989, pp. 303-312.
29. ZAVADSKAS, E. K., Z. TURSKIS, **A New Logarithmic Normalization Method in**

Games Theory, Informatica, vol.19, no. 2, 2008, pp. 303-314.

30. CELEN, A., **Comparative Analysis of Normalization Procedures in TOPSIS Method: with an Application to Turkish Deposit Banking Market**, Informatica, vol. 25, no. 2, 2014, pp. 185-208.

31. CHAKRABORTY, S., C. YEH, **A Simulation based Comparative Study of Normalization Procedures in Multiattribute Decision Making**, In: Proceedings of the 6th WSEAS International Conference on Artificial Intelligence, Knowledge Engineering and Data Bases, Corfu Island, Greece, February 16-19, 2007.

32. STANUJKIC, D., B. DJORDJEVIC, M. DJORDJEVIC, **Comparative Analysis of Some Prominent MCDM Methods: A Case of Ranking Serbian Banks**, Serbian J. of Man., vol. 8(2), 2013a, pp. 213-241.

33. Weitendorf, D., **Beitrag zur Optimierung der raumlichen Struktur eines Gebaude**. Dissertation A, Hochschule fur Architektur und Bauwesen, Weimar, 1976.

34. Juttler, H., **Untersuchungen zur Fragen der Operationsforschung und ihrer Anwendungsmoglichkeiten auf okonomische Problemstellungen unter besonderer Berucksichtigung der Spieltheorie**, Dissertation A an der Wirtschaftswissenschaftlichen Fakultat der Humboldt - Universitat, Berlin, 1966.

Appendix A

The use of and the influence of the compensation coefficient impact on the selection of the alternative that to a great extent meets the decision maker's preferences

In this section, the use and the impact of the compensation coefficient c_i on the selection of the most suitable alternative is considered.

The analysis starts from Table A1, which contains the normalized performance ratings for the five alternatives, wherein normalization was performed by using the procedure proposed by Stanujkic *et al.* (2013), i.e. by using Equation (2) and Equation (3).

The considered alternatives have different distances from the preferred performance ratings of the criteria as well as a different number of deviations from the preferred levels. For the sake of simplicity, a choice was made so that all the criteria considered herein had the same importance, i.e. w_j = 0.333, and all the alternatives had the same sums of normalized deviations from the desired levels, i.e. $\sum r_{ij}=0.2$.

The overall performance ratings of the considered alternatives, obtained by using Equation (1), are accounted for in Table A2.

The adjusted overall performance rating of the alternatives, S_i', for λ =0.5 and γ =1, are shown in Table A3.

The alternative A_1 has a high value of S_1 on the basis of a single criterion, C_1, which affects the high values of $d_i^{\max}$ and $\bar{S}_i^+$, as well as c_1. Therefore, the alternative A_1 is ranked low on the basis of the S_i' .

The values of the alternatives A_2, A_3 and A_4 for their respective S_i are achieved on the basis of two or three criteria. This affects the lower values of their $d_i^{\max}$ and $\bar{S}_i^+$, as well as c_i, for which reason these alternatives are better-ranked than the alternative A_1.

The alternative A_5 achieves its $S_i^{'}$ based on three criteria, whereas in relation to the criteria C_3, it does not reach the preferred performance rating. The high value of its $\bar{S}_i^+$ is primarily achieved on the basis of the significant deviations of the criteria C_1 and C_2. However, the significant deviations also affect the values of d_5^{max} and $\bar{S}_5^+$, so that its final rating is low, too.

The detailed analysis of the impact of the coefficient λ on the selection of the most acceptable alternative is presented in Table A4.

As it is shown in Table A4, it is evident that the coefficient λ has an impact on the ranking order of the alternatives, as well as that by varying it the decision-maker can attribute a different significance to the maximum deviation from the preferred performance ratings.

Table A1. The normalized performance ratings and the weights of the criteria

	C_1	C_2	C_3	$\sum r_{ij}$
w_j	0.333	0.333	0.333	
A_1	0.2	0	0	0.2
A_2	0.15	0.05	0	0.2
A_3	0.1	0.1	0	0.2
A_4	0.1	0.05	0.05	0.2
A_5	0.15	0.15	-0.1	0.2

Table A2. The ranking results obtained on the basis of S_i

	$S_i=\sum w_j r_{ij}$	Rank
A_1	0.067	1
A_2	0.067	1
A_3	0.067	1
A_4	0.067	1
A_5	0.067	1

Table A3. The ranking results obtained on the basis of $S_i^{'}$

	d_i^{max}	S_i^+	n_i^+	$\bar{S}_i^+$	c_i	S_i	$S_i^{'}$	Rank
A_1	0.067	0.067	1	0.067	0.067	0.067	0.000	5
A_2	0.050	0.067	2	0.033	0.042	0.067	0.025	3
A_3	0.033	0.067	2	0.033	0.033	0.067	0.033	2
A_4	0.033	0.067	3	0.022	0.028	0.067	0.039	1

Table A4. The ranking results obtained by using different values of the coefficient λ

	λ=1			λ=0.5			λ=0		
	c_i	$S_i^{'}$	Rank	c_i	$S_i^{'}$	Rank	c_i	$S_i^{'}$	Rank
A_1	0.067	0.000	5	0.067	0.000	5	0.067	0.000	5
A_2	0.050	0.017	3	0.042	0.025	3	0.033	0.033	2
A_3	0.033	0.033	1	0.033	0.033	2	0.033	0.033	2
A_4	0.033	0.033	1	0.028	0.039	1	0.022	0.044	1
A_5	0.050	0.017	4	0.050	0.017	4	0.050	0.017	4