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COMPARATIVE ANALYSIS OF SOME PROMINENT MCDM METHODS: A CASE OF RANKING SERBIAN BANKS

Dragisa Stanujkic*, Bojan Đorđević and Mira Đorđević

Faculty of Management Zajecar, Megatrend University, Park suma "Kraljevica" bb, 19000 Zajecar, Serbia

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Abstract

In the literature, many multiple criteria decision making methods have been proposed. There are also a number of papers, which are devoted to comparison of their characteristics and performances. However, a definitive answer to questions: which method is most suitable and which method is most effective is still actual. Therefore, in this paper, the use of some prominent multiple criteria decision making methods is considered on the example of ranking Serbian banks. The objective of this paper is not to determine which method is most appropriate for ranking banks. The objective of this paper is to emphasize that the use of various multiple criteria decision making methods sometimes can produce different ranking orders of alternatives, highlighted some reasons which lead to different results, and indicate that different results obtained by different MCDM methods are not just a random event, but rather reality.

Keywords: MCDM, SAW, MOORA, GRA, CP, VIKOR, TOPSIS

1. INTRODUCTION

The multiple criteria decision making (MCDM) can be generally described as the process of selecting one from a set of available alternatives, or ranking alternatives, based on a set of criteria, which usually have a different significance.

During the second half of the 20th century, MCDM was one of the fastest growing areas of operational research and because of them many MCDM methods have been proposed. From many of the proposed MCDM methods, we shall state some of the most prominent, such as: Simple Additive Weighting (SAW) method (MacCrimon,

* *Corresponding author: dragisa.stanujkic@fmz.edu.rs*

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1968), Compromise programming (Zeleny, 1973; Yu, 1973), Analytic Hierarchy Process (AHP) method (Saaty, 1980), Technique for Ordering Preference by Similarity to Ideal Solution (TOPSIS) method (Hwang & Yoon, 1981), Preference Ranking Organisation Method for Enrichment Evaluations (PROMETHEE) method (Brans & Vincke, 1985), Grey Relational Analysis (GRA) proposed by Deng (1989) as part of Grey system theory, ELimination and Choice Expressing REality (ELECTRE) method (Roy, 1991), COmplex PRoportional ASsessment (COPRAS) method (Zavadskas et al., 1994), VIKOR (VIsekriterijumska optimizacija i KOmpromisno Resenje in Serbian, means Multicriteria Optimization and Compromise Solution) method (Opricovic, 1998), Additive Ratio Assessment (ARAS) method (Zavadskas & Turskis, 2010), Multi-Objective Optimization on the basis of Ratio Analysis (MOORA) method (Brauers & Zavadskas, 2006) and Multi-Objective Optimization by Ratio Analysis plus Full Multiplicative Form (MULTIMOORA) method (Brauers & Zavadskas, 2010a).

In the past, these methods have been used to solve many problems, which are documented in many professional and scientific journals. Numerous prominent papers presented research in MCDM, which is why we omit the reference to them in this paper.

The above-mentioned MCDM methods transform multiple criteria decision-making process, i.e., Multiple Criteria optimization, in a single criterion decision-making optimization, which is much easier to solve. A number of authors have been identifying different phases (stages) in MCDM process, from which, in order to more clearly point out the objectives of this study, the following phases are emphasized:

- criteria weights determination,
- normalization,
- aggregation, and
- selection.

A typical MCDM problem can be precisely presented in the following form:

$$D = [x_{ij}]_{m \times n} \qquad W = [w_j]_n \tag{1}$$

where D is decision matrix, x_{ij} is performance of i-th alternative with respect to j-th criterion, W is weight vector, w_j is weight of j-th criterion, $i = 1,2, \ldots m$; m is the number of compared alternatives, $j = 1,2, ..., n$; n is the number of the criteria.

Information stored in a decision matrix is usually incommensurable, i.e. performance ratings in relation to different criteria are usually expressed using different units of measure. Therefore, data should be transformed into comparable values, using a normalization procedure. For normalization, numerous procedures, also known as normalization methods, have been formed. A comprehensive overview of some normalization procedures were given by Zavadskas and Turskis (2008).

Evaluation criteria involved in the MCDM models can be classified in several ways. In this paper two, very significant classification, of evaluation criteria are considered.

In relation to required direction of optimization, there are two types of evaluation criteria, namely:

- benefit type criteria, i.e., the higher rating is better; and,
- cost type criteria, i.e., the lower rating is better.

Evaluation criteria can also be classified as subjective and objective. Subjective criteria have a qualitative nature, i.e., performance ratings of these criteria are rather expressed using quantitative values, often using linguistic variables. In contrast, objective criteria have a quantitative nature, i.e., the performance ratings of these criteria are rather expressed using quantitative values, which is why performance ratings of these criteria can be much more precisely determined.

In MCDM, evaluation criteria usually have different importance (weights), and it is also important that weights of criteria often have a large impact on selection of the most acceptable alternative.

N-dimensional information, stored in a MCDM model, can be transformed into one-dimensional using MCDM methods. As is mentioned above, over time, many MCDM methods were proposed. They differ in the approach used to determine the most appropriate alternative, that is, they have different aggregation procedures, use different normalization methods and have different treatment for the cost and benefit criteria.

Therefore, 'Which is the best method for a given problem?' has become one of the most important and challenging questions (Triantaphyllou, 2000). However, the question 'Whether all MCDM methods give the same results?' is also important and actual too.

In the scientific and professional journals many significant papers are published where the comparison of some of the MCDM methods was presented, and the results achieved by their application to the case of solving real-world problems. From many, following are emphasized here: Aghajani et al. (2012), Zolfani et al. (2012), Antucheviciene et al. (2011), Savitha and Chandrasekar (2011), Podvezko (2011), Zavadskas et al. (2010b), Ginevicius et al. (2010b, 2008), Ginevicius and Podvezko (2009), Caterino et al. (2009), Opricovic and Tzeng (2004).

In this paper, one case study of ranking Serbian banks was considered, using some of the most prominent MCDM methods. This paper examines comparison of results that were achieved using these methods.

Therefore, this paper is organized as follows: In section 2 of this paper, one brief review of some of the most prominent MCDM method is given. In section 3, a case study of ranking Serbian banks, based on objective criteria, is considered. After that, in section 3, several variants of discussed case study are discussed with the aim to determine whether different normalization methods, different aggregation procedures and different criteria weight have impact on the selection of the most acceptable alternative, or a ranking order of the considered alternatives. Finally, section 4 presents conclusions.

2. A BRIEF COMPARATIVE OVERVIEW OF SOME OF THE MOST PROMINENT MCDM METHODS

In this section, a brief comparative overview of some prominent MCDM methods is presented. In order to perform their clearer and more precise comparison, some labels in formulas or parts of formulas are adjusted with accepted style.

From many methods which can be used for selecting and/or ranking different alternatives, in this paper, we consider following: SAW, ARAS, COPRAS, MOORA, GRA, CP, VIKOR and TOPSIS method.

One of main objectives that had been

planned as a result of this study was the formation of a simple to use MCDM model for ranking commercial banks. Therefore, in this study the MCDM methods that require significant user interaction during problem solving was process omitted, such as ELECTRE and PROMETHEE methods. This is the reason why the AHP method was also omitted. However, the pairwise comparison approach, taken from the AHP method was used to determine the weights of criteria.

2.1. Simple Additive Weighting (SAW)

Simple additive weighting (SAW) method is probably the simplest, best known and formerly often used MCDM method. The SAW method uses a simple aggregation procedure, which can be presented using the following formula:

$$Q_i = \sum_{j=1}^{n} w_j r_{ij}\,, \tag{2}$$

where Q_i is overall ranking index of i-th alternative; w_j is weight of j-th criterion, r_{ij} is normalized performance of i-th alternative with respect to j-th criterion, i = 1,2, … m; and j = 1,2, ..., n.

In SAW method, the alternatives are ranked on the basis of their Q_i in ascending order, and the alternative with the highest value of Q_i is the best ranked. The best ranked, or the most preferable, alternative, based on the SAW method, A^*_{SAW} can be determined using the following formula:

$$A^*_{SAW} = \left\{ A_i = \max_i Q_i \right\}. \tag{3}$$

The aggregation procedure in SAW method makes no difference between cost and benefit type criteria. Therefore, cost type criteria must be transformed into benefit type criteria during normalization.

Formerly, this form of transformation was often stated as a weakness of SAW method. However, in some actual fuzzy extensions of prominent MCDM methods, cost type criteria also are transformed into benefit type criteria, such as in Saremi et al. (2009), Mahdavi et al. (2008), Wang and Elhag (2006).

SAW method can be used with different normalization procedures. Linear scale transformation - Max method is probably the most frequently used normalization procedure, but there are also other approaches.

Some typical normalization procedures, used in the SAW method, are given below:

a. Linear Scale Transformation, Max method

$$r_{ij} = \begin{cases} x_{ij} / x_j^+ ; & j \in \Omega_{\max} \\ x_j^- / x_{ij} ; & j \in \Omega_{\min} \end{cases} \tag{4}$$

b. Linear Scale Transformation - Sum method

$$r_{ij} = \begin{cases} x_{ij} \Big/ \sum_{i=1}^{n} x_{ij} ; & j \in \Omega_{\max} \\ (1/x_{ij}) \Big/ \sum_{i=1}^{n} (1/x_{ij}) ; & j \in \Omega_{\min} \end{cases} \tag{5}$$

c. Vector normalization

$$r_{ij} = \begin{cases} x_{ij} \Big/ \left(\sum_{i=1}^{n} x_{ij}^2 \right)^{1/2} ; & j \in \Omega_{\max} \\ 1 - \left(x_{ij} \Big/ \left(\sum_{i=1}^{n} x_{ij}^2 \right)^{1/2} \right) ; & j \in \Omega_{\min} \end{cases} \tag{6}$$

d. Linear Scale Transformation, MaxMin method

$$r_{ij} = \begin{cases} \dfrac{x_{ij} - x_j^-}{x_j^+ - x_j^-}; & j \in \Omega_{\max} \\ \dfrac{x_j^+ - x_{ij}}{x_j^+ - x_j^-}; & j \in \Omega_{\min} \end{cases} \quad (7)$$

where x_j^+ is the largest performance ratings and x_j^- is the smallest performance rating of j-th criterion, Ω_{max} and Ω_{min} are sets of benefit and cost criteria, respectively.

As already stated, SAW method was previously frequently used. However, the usage of some recent MCDM methods significantly reduced the use of SAW method, but this simple and effective MCDM method is not forgotten. Moreover, it continues to be developed and used, as proven by its fuzzy and grey extensions, such as: Chen (2012), Turskis et al. (2010), Chou et al. (2008).

SAW method and its extensions are also frequently used in the case of application and comparison of several MCDM methods, such as in Zolfani et al. (2012), Chen (2012), Turskis et al. 2010.

2.2. (ARAS) A new Additive Ratio ASessment

A new additive ratio assessment (ARAS) method is newly proposed MCDM method. In this method, the most acceptable alternative is determined on the basis of degree of utility Q_i, which can be calculated using the following formula:

$$Q_i = \frac{S_i}{S_0}; \; i = 1,2,\ldots,m \quad (8)$$

where S_i is overall performance index of i-th alternative, S_0 is overall performance index of optimal alternative, and S_0 usually has a value which is 1.

The alternatives are ranked on the basis of their Q_i in ascending order, and the alternative with the highest value of Q_i is the best ranked. The best ranked alternative, based on the ARAS method, A^*_{ARS}can be determined using the following formula:

$$A^*_{ARS} = \left\{ A_i = \max_i Q_i \right\}; \; i = 1,2,\ldots,m \; . \quad (9)$$

The specificity of ARAS method, compared to other methods, is the introduction of the optimal alternative A_0. The performances of the optimal alternative are determined on the basis of decision makers' preferences. If the decision maker has no preference about some criterion, its optimal performance is determined as follows:

$$x_{0j} = \begin{cases} \max_i x_{ij}; & j \in \Omega_{\max} \\ \min_i x_{ij}; & j \in \Omega_{\min} \end{cases} . \quad (10)$$

The ARAS method uses the same aggregation procedure as the SAW method, and therefore the overall performance index of any alternative can be determined as follows:

$$S_i = \sum_{j=1}^{n} w_j r_{ij} \; . \quad (11)$$

The normalized performance ratings in ARAS are calculated by using the following formula:

$$r_{ij} = \begin{cases} \dfrac{x_{ij}}{\sum_{i=0}^{m} x_{ij}}; & j \in \Omega_{\max} \\ \dfrac{1/x_{ij}}{\sum_{i=0}^{m} 1/x_{ij}}; & j \in \Omega_{\min} \end{cases} . \quad (12)$$

The ARAS method can be classified as an effective and easy to use MCDM method. Although it is newly proposed, it has been applied to solve various decision-making problems, and its fuzzy and grey extension have also been proposed, named ARAS-F (Turskis & Zavadskas, 2010b) and ARAS-G (Turskis & Zavadskas, 2010a). From many papers where the use of ARAS method and its extensions is discussed, just few are mentioned here: Zavadskas et al. (2012), Turskis et al. (2012), Kersuliene and Turskis (2011), Susinska et al. (2011), Bakshi and Sarkar (2011).

2.3. (COPRAS) COmplex PRoportional ASsessment

Complex proportional assessment (COPRAS) method, compared to previous methods, has slightly more complex aggregation procedure, but it does not require transformation of cost to benefit type criteria. The overall ranking index, of each alternative, can be calculated using the following formula:

$$Q_i = S_{+i} + \frac{S_{-\min} \sum_{i=1}^{m} S_{-i}}{S_{-i} \sum_{i=1}^{m} \frac{S_{-\min}}{S_{-i}}}, \qquad (13)$$

where

$$S_{+i} = \sum_{j \in \Omega_{\max}} w_j \cdot r_{ij}, \qquad (14)$$

$$S_{-i} = \sum_{j \in \Omega_{\min}} w_j \cdot r_{ij}, \qquad (15)$$

$$S_{-\min} = \min_i S_{-i}. \qquad (16)$$

The Formula (13) can be also written in following simplified form:

$$Q_i = S_{+i} + \frac{\sum_{i=1}^{m} S_{-i}}{S_{-i} \sum_{i=1}^{m} \frac{1}{S_{-i}}}. \qquad (17)$$

The alternatives, by COPRAS method, are ranked on the basis of their Q_i, and the alternative with the highest value of Q_i is the best ranked. The best ranked alternative, based on the COPRAS method, A^*_{CPS} can be determined using the following formula:

$$A^*_{CPS} = \left\{ A_i = \max_i Q_i \right\} \qquad (18)$$

For normalization, COPRAS method uses linear transformation - Sum method, without transformation of cost to benefit type criteria. The normalized performance ratings in COPRAS are calculated using the following formula:

$$r_{ij} = \frac{x_{ij}}{\sum_{i=1}^{n} x_{ij}}. \qquad (19)$$

Description of COPRAS methods and possibilities of its application are published in a large number of papers, such as: Zavadskas et al. (2001), Zavadskas et al. (2004), Kaklauskas et al. (2005), Kaklauskas et al. (2006).

As for other MCDM methods, fuzzy and grey extension is also proposed for COPRAS method. Fuzzy extension of COPRAS method, COPRAS-F method was introduced by Zavadskas and Antucheviciene (2007), and it used to analyze abandoned building's regeneration alternatives in Lithuanian rural areas. Zavadskas et al. (2008a) proposed a grey extension of COPRAS methods, called GOPRAS-G method, and used it to select dwelling house walls, project managers (Zavadskas et al. 2008b), contractors (Zavadskas et al. 2008c), and so on.

Since then, the COPRAS method and its extensions has been applied for solving decision-making problems. As some significant examples of applying COPRAS and COPRAS-G method can be mentioned:

Banaitiene et al. (2008), Zavadskas et al. (2008a; 2008b; 2010a), Mazumdar et al. (2010), Podvezko et al. (2010) and Madhuri et al. (2010).

A significant number of papers published in the last two years indicate that the COPRAS method is very actual MCDM method. From many papers few are mentioned here, such as: Zavadskas et al. (2011), Antucheviciene and Zavadskas (2012), Chatterjee and Chakraborty (2012), Fouladgar et al. (2012) and Popovic et al. (2012).

2.4. (MOORA) The Multi-Objective Optimization by Ratio Analysis

The multi-objective optimization by ratio analysis (MOORA) method consists of two parts, which are named: Ratio system approach and Reference point approach. These two parts are based on the same type of normalization.

Ratio system approach. The basic idea of the Ratio system approach of the MOORA method is to determine the overall performance index of alternative as the difference between sums of weighted normalized performance of benefit and cost criteria, as follows:

$$Q_i = \sum_{j \in \Omega_{\max}} w_j r_{ij} - \sum_{j \in \Omega_{\min}} w_j r_{ij} \ . \tag{20}$$

The alternatives are ranked on the basis of their S_i in ascending order, and the alternative with the highest value of S_i is the best ranked. The best ranked alternative, based on the Reference point approach of the MOORA method, A^*_{MRS} can be determined using the following formula:

$$A^*_{MRS} = \left\{ A_i = \max_i Q_i \right\} \ . \tag{21}$$

Reference point approach. After considering the most important reference point metrics, Brauers and Zavadskas (2006) emphasize that the min-max metric is the best choice amongst them. Therefore, for optimization based on the reference point approach Brauers and Zavadskas (2006) proposed the following formula:

$$\min_i \left\{ \max_j (w_j \mid r_j - r_{ij} \mid) \right\} . \tag{22}$$

The best ranked alternative, based on Reference point approach of the MOORA method, A^*_{MRP} can be determined using the following formula:

$$A^*_{MRP} = \left\{ A_i = \min_i \left\{ \max_j (w_j \mid r_j - r_{ij} \mid) \right\} \right\} \ . \tag{23}$$

For normalization, MOORA method uses vector normalization procedure, without transformation of cost to benefit type criteria. The normalized performance ratings in MOORA method are calculated using the following formula:

$$r_{ij} = \frac{x_{ij}}{\left(\sum_{i=1}^{n} x_{ij} \right)^{1/2}} \ . \tag{24}$$

The MOORA method is also a newly proposed MCDM method. Although the MOORA is a newly proposed method, it is applied to solve many economic, managerial and construction problems, and is presented in a significant number of papers published in journals, such as: Brauers and Zavadskas (2006, 2009), Brauers et al. (2008), Kalibatas and Turskis (2008), Brauers and Ginevicius (2009), Ginevicius et al. (2010a), Chakraborty (2011).

Brauers and Zavadskas (2010a) also presented MULTIMOORA method, as an extension of MOORA method with full multiplicative form. As MOORA method, MULTIMOORA method is also widely used for solving numerous problems. From many papers few are mentioned here: Brauers and Zavadskas (2010a, 2010b, 2011), Brauers and Ginevicius (2010), Balezentis et al. (2010), Kracka et al. (2010), Balezentis, A. and Balezentis, T. (2011).

Similar to other MCDM methods, for MOORA and MULTIMOORA some extensions have been proposed. Brauers et al. (2011) proposed first fuzzy extension of the MOORA method, or more precisely MULTIMOORA method. Balezentis et al. (2012) further modified fuzzy MULTIMOORA, and proposed a fuzzy extension named MULTIMOORA-FG, which includes the use of linguistic variables and group decision making.

Besides these, there are other extensions, such as: Karande and Chakraborty (2012), and Dey et al. (2012) proposed fuzzy extensions of Ratio system approach of the MOORA method. Stanujkic et al. (2012a, 2012b) proposed a grey extension of the MOORA method.

Actuality of MOORA method also confirms a significant number of papers which have been published in numerous journals. In addition to the previously mentioned papers, below are given some new and significant, such as: Brauers and Zavadskas (2012), Chakraborty and Karande (2012), Archana and Sujatha (2012).

2.5. (CP) Compromise Programming

2.5. Compromise programming (CP) is based on Minkowski L_p metric. In CP the best alternative should have the shortest distance from the reference point (i.e. ideal solution), and its aggregation procedure can be shown by the following formula:

$$\min L_{p,i} = \left\{ \sum_{j=1}^{n} w_j^p \left(\frac{x_j^* - x_{ij}}{x_j^* - x_j^-} \right)^p \right\}^{\frac{1}{p}} , \tag{25}$$

where $L_{p,i}$ is distance metric of i-th alternative for a given parameter p, x_j^* and x_i^- are the most preferable and the worst performance rating of j-th criterion, and p is metric, $p \in [1, \infty)$.

The parameter p, in formula (25) is used to represent the importance of the maximal deviation from the reference point. By varying the parameter p from 1 to infinity, it is possible to move from minimizing sums of individual deviations to minimizing the maximal deviation to the ideal point.

The most preferable x_j^* and the worst x_i^- performance rating of j-th criterion are determined using the following formulae:

$$x_j^* = \begin{cases} \max\limits_i x_{ij}; & j \in \Omega_{\max} \\ \min\limits_i x_{ij}; & j \in \Omega_{\min} \end{cases} , \tag{26}$$

$$x_j^- = \begin{cases} \min\limits_i x_{ij}; & j \in \Omega_{\max} \\ \max\limits_i x_{ij}; & j \in \Omega_{\min} \end{cases} . \tag{27}$$

The alternatives are ranked on the basis of their $L_{p,i}$ in descending order, and the alternative with the lowest value of $L_{p,i}$ is the best ranked. The best ranked alternative, based on the CP method, A^*_{CP} can be determined using the following formula:

$$A_{CP}^* = \left\{ A_i = \min_i L_{p,i} \right\} . \tag{28}$$

Unlike the previously described MCDM methods, the aggregation procedure used in CP method also performs normalization of ratings, and because of that the normalization procedure does not have to be performed.

In the past, the Compromise

programming methodology has made a prominent use in the field of water resources management, but it is also applied in many other fields, such as forest management and economy. Some of the more important studies that are based on the use of Compromise programming can be specified in the following: Wu and Chang (2004), Bender and Simonovic (2000), Poff et al. (2010), Andre et al. (2007), Tecle et al. (1998), Simonovic et al. (1992), Simonovic and Burn (1989), Duckstein and Opricovic (1980).

Compared with other MCDM methods, Compromise programming is significantly less used.

Similar to other MCDM methods, some extensions of Compromise programming are proposed, such as: Prodanovic and Simonovic (2003), Bilbao-Terol et al. (2006).

2.6. (GRA) Grey Relational Analysis

Grey relational analysis (GRA) was proposed as part of Grey system theory. Similar to the TOPSIS method, GRA is based on the use of the distance from an ideal solution. In the literature, many authors have discussed the use of different variants of the GRA, from which we, in this paper, present one simple and efficient which can be used when ratings are expressed with the crisp numbers.

In GRA, the most appropriate alternative is determined on the basis of Grey relational grade, which can be calculated using the following formula:

$$G_i = \frac{1}{n}\sum_{j=1}^{n} w_j \xi_{ij} , \quad (29)$$

where ξ_{ij} is the grey relational coefficient of i-th alternative to the j-th criterion.

The grey relational coefficient of each alternative can be calculated using the following formula:

$$\xi_{ij} = \frac{\min_i \min_j | r_j^* - r_{ij} | + \varsigma \max_i \max_j | r_j^* - r_{ij} |}{| r_j^* - r_{ij} | + \varsigma \max_i \max_j | r_j^* - r_{ij} |} , \quad (30)$$

where r_j^* is most preferable normalized performance rating of i-th alternative according to j-th criterion, ς is the distinguish coefficient, and $\varsigma \in [0,1]$.

The coordinates of the ideal point, i.e., the most preferable normalized ratings in relation to the criteria, can be determined using the following formula:

$$A^* = \left\{ r_1^*, r_2^*, \ldots, r_n^* \right\} =$$

$$= \left\{ \max_i r_{ij} / j \in \Omega_{max}), (\min_i r_{ij} / j \in \Omega_{min}) \right\} , \quad (31)$$

where A^* is ideal point, also known as ideal solution, r_j^* is j-th coordinate of ideal point, r_{ij} is normalized performance rating of i-th alternative to the j-th criterion, and Ω_{max} and Ω_{min} are sets of benefit and cost criteria, respectively.

Different authors use GRA with various normalization procedures, with or without transformation of cost type to benefit type criteria. In this paper, the use of GRA without transformation of cost type to benefit type criteria was discussed. Therefore, the normalized performance ratings can be calculated by using one of the following formulae:

$$r_{ij} = \frac{x_{ij}}{x^+} , \quad (32)$$

$$r_{ij} = \frac{x_{ij} - x_j^-}{x_j^+ - x_j^-} , \quad (33)$$

or the formulae (19) and (24).

After determining overall ranking index for each alternative, in GRA approach the alternative with smallest overall ranking index has higher priority (rank) and the most acceptable alternative can be determined by the following formula:

$$A^*_{GRA} = \left\{ A_i = \min_i G_i \right\} . \quad (34)$$

Beside the above presented GRA approach, in the literature also are proposed some complex variant of GRA which are based on the well-known concept used in TOPSIS method, i.e., TOPSIS based GRA approach. Due to a clearer presentation, in this paper TOPSIS based GRA approach is marked as GRA(T) approach.

In the GRA(T) approach, the best ranked alternative can be determined using the following formula:

$$G_i = \frac{g_i^*}{g_i^-} , \quad (35)$$

where:

$$g_i^* = \sum_{j=1}^{n} w_j \xi_{ij}^* , \quad (36)$$

$$\xi_{ij}^* = \frac{\min_i \min_j | r_j^* - r_{ij} | + \varsigma \max_i \max_j | r_j^* - r_{ij} |}{| r_j^* - r_{ij} | + \varsigma \max_i \max_j | r_j^* - r_{ij} |} , \quad (37)$$

and,

$$g_i^- = \sum_{j=1}^{n} w_j \xi_{ij}^- , \quad (38)$$

$$\xi_{ij}^- = \frac{\min_i \min_j | r_j^- - r_{ij} | + \varsigma \max_i \max_j | r_j^- - r_{ij} |}{| r_j^- - r_{ij} | + \varsigma \max_i \max_j | r_j^- - r_{ij} |} . \quad (39)$$

As it can be concluded from the above, selection of the best placed alternative using TOPSIS based GRA approach is based on the ratio between distance of an alternative from the ideal and non-ideal solution.

Therefore, in TOPSIS based GRA approach, there are two characteristic points in *n*-dimensional space, i.e. ideal and anti-ideal point, also known as ideal and anti-ideal solution.

The ideal point is determined as already shown in formula (31). The anti-ideal point is determined as follows:

$$A^- = \left\{ r_1^-, r_2^-, \dots, r_n^- \right\} =$$

$$= \left\{ \min_i r_{ij} / j \in \Omega_{max}), (\max_i r_{ij} / j \in \Omega_{min}) \right\} , \quad (40)$$

where A^- is anti-ideal point, r_{ij}^- is j-th coordinate of anti-ideal point.

GRA approach is used to solve many decision-making problems. The achieved results, and the usability of the GRA approach, are presented in a number of papers published in many significant journals. From many papers, some most prominent are mentioned here: Chan and Tong (2007), Tosun (2006), Fung (2003), Lin et al. (2002), Fu et al. (2001).

2.7. VIKOR method

The development of the VIKOR method, similar to CP method, also started from the Minkowski L_p metric, already shown by formula (25). The VIKOR method uses two characteristic metrics to formulate ranking measure, $p = 1$ and $p \to \infty$, for which the formula (25) gets the following specific forms:

$$S_i = \sum_{j=1}^{n} w_j (x_j^* - x_{ij}) / (x_j^* - x_j^-) \text{ ; for } p = 1 \text{, and} \quad (41)$$

$$R_i = \max_j [w_j (x_j^* - x_{ij}) / (x_j^* - x_j^-)] \text{ ; for } p \to \infty , \quad (42)$$

where S_j and R_j as the average and the worst group score of i-th alternative.

The VIKOR method is based on idea of ideal and compromise solution, and the overall ranking index for each alternative is calculated using the following formula:

$$Q_i = v\frac{(S_i - S^*)}{(S^- - S^*)} + (1-v)\frac{(R_i - R^*)}{(R^- - R^*)} \tag{43}$$

where:

$$S^* = \min_i S_i \;, \tag{44}$$

$$S^- = \max_i S_i \;, \tag{45}$$

$$R^* = \min_i R_i \;, \tag{46}$$

$$R^- = \max_i R_i \;, \tag{47}$$

and ν is significance of the strategy of criteria (objectives) majority which value is usually set to be 0.5.

Compared to other previously considered MCDM methods, determination of the most appropriate alternative using VIKOR method is more complex, and it can be described as follows: The alternatives are sorted by values *S*, *R* and *Q* in the ascending order. The most acceptable alternative *A′* is the one with the minimum value of *Q*, if two complementary conditions are satisfied (Opricovic & Tzeng 2004):

C*1. *Acceptable advantage: The condition ***C*1** is satisfied if the following equation is satisfied:

$$Q(A'') - Q(A') \geq DQ \;, \tag{48}$$

where:

$$DQ = 1/(m-1) \text{, and} \tag{49}$$

A″ is the alternative having the second position in the ranking list by *Q*, and m is the number of alternatives.

C*2. *Acceptable stability in decision making: Alternative *A′* must also be the best ranked by *S* and/or *R*.

If one of these conditions is not satisfied, then, a set of compromise solutions with the advantage rate is proposed instead of most acceptable alternative (Antucheviciene et al. 2011). This set will consist of:

- the alternatives *A′* and *A″*; if only condition ***C*2** is not satisfied, or
- the alternatives $A', A'', \ldots, A^n$; if conditions ***C*1** and ***C*2** are not satisfied, where A^n is determined by the relation:

$$Q(A^n) - Q(A') \leq DQ \;. \tag{50}$$

The VIKOR method has been used for solving numerous MCDM problems. In order to solve complex decision-making problems Opricovic (2007) proposed a fuzzy extension of VIKOR method, named VIKOR-F. Sayadi et al. (2009) also proposed a grey extension of VIKOR method.

Numbers of papers have been published where VIKOR or VIKOR-F was applied. As more significant, the following works can be mentioned: Tong et al. (2007), Rao (2008), Chen and Wang (2009), Yu-Ping et al. (2009), Kaya and Kahraman (2010).

The important characteristic of this method is that the number of papers published in the last two years has increased significantly compared to the previous period. From many papers few are mentioned here: Opricovic, S. (2011), Jahan et al. (2011), San Cristobal (2011), Roostaee et al. (2012), Chiu et al. (2012), Liu et al. (2012).

2.8. TOPSIS method

The TOPSIS method is one of the most widely used MCDM methods. The basic principle of TOPSIS method is that the best alternative should have the shortest distance from the ideal solution and the farthest distance from the anti-ideal solution. A relative distance of each alternative from ideal and anti-ideal solution is obtained as:

$$C_i = \frac{d_i^-}{d_i^+ + d_i^-} , \tag{51}$$

where d_i^+ and d_i^- are separation measures of alternative i from the ideal and anti-ideal solution, respectively; C_i is relative distance of alternative i to the ideal solution, and $C_i \in [0,1]$.

The largest value of the criterion C_i correlates with the best alternative. Therefore, in TOPSIS method, the alternatives are ranked on the basis of their C_i in ascending order, and the alternative with the highest value of C_i is the best ranked. The best ranked, or the most preferable, alternative A_{TPS}^* can be determined using the following formula:

$$A_{TPS}^* = \left\{ A_i = \max_i C_i \right\} . \tag{52}$$

The separation measures of each alternative, from the ideal and anti-ideal solution, are computed using following formulae:

$$d_i^+ = \left\{ \sum_{j=1}^{n} \left[w_j (r_{ij} - r_i^+) \right]^2 \right\}^{1/2} \text{, and} \tag{53}$$

$$d_i^- = \left\{ \sum_{j=1}^{n} \left[w_j (r_{ij} - r_i^-) \right]^2 \right\}^{1/2} . \tag{54}$$

The ideal A^* and the anti-ideal A^- solution in TOPSIS method can be determined using the already mentioned formulae (31) and (40), respectively.

It can be seen from the formulae (53) and (54) that ordinary TOPSIS method is based on the Euclidean distance. In addition to Euclidean distance, in the literature are also presented some examples where TOPSIS method was used with other metrics, especially with a city-block distance (Chang et al., 2010; Shanian & Savadogo, 2006; Yoon & Hwang, 1980).

TOPSIS method, as well as the MOORA method, uses Vector normalization procedure, already given by formula (24). However, in the literature is also discussed the use of TOPSIS method with other normalization procedures, especially when its fuzzy extensions are proposed, such as in Saremi et al. (2009), Yang and Hung (2007), Wang and Elhag (2006), and so on.

TOPSIS is one of the most actual MCDM methods, which is confirmed by a number of papers published in scientific journals in 2012. From a very large number, just a few are mentioned here, such as: Tansel (2012), Ravi (2012), Huang and Peng (2012), Buyukuzkan (2012), Arslan and Cunkas (2012).

In the past, TOPSIS method was used rather frequently. This is also confirmed by a number of papers, such as: Boran et al. (2009), Dagdeviren et al. (2009), Ertugrul and Karakasoglu (2009), Wang and Chang (2007).

Similar to other MCDM methods, a number of extensions have been proposed for TOPSIS method, such as: Dagdeviren et al. (2009), Ashtiani et al. (2009), Shih et al. (2007), Wang and Elhag (2006), Jahanshahloo et al. (2006), Chen (2000).

3. A CASE STUDY AND DISCUSSION OF RESULTS

In this section we consider a case study of ranking some Serbian commercial banks. In order to perform more objective conclusions in terms of the applicability of MCDM methods, the influence which the weights of criteria, the used approaches and the applied normalization procedure have on the selection of the most appropriate alternative and obtained ranking orders of alternatives, is also taken into consideration in this section.

3.1. A Case Study: The Case of ranking Serbian banks

In the literature, many papers have been devoted to the ranking of banks, as well as to determining banks' performances. Among many, here are mentioned only a few, such as: Ferreira et al. (2012), Stankeviciene and Mencaite (2012), Brauers et al. (2012), Cehulic et al. (2011), Ginevicius and Podviezko (2011), Ginevicius et al. (2010c), Cetin and Cetin (2010), Wu et al. (2009), Rakocevic and Dragasevic (2009), Ginevicius and Podvezko (2008), Hunjak and Jakocevic (2001), Yeh (1996), Sherman and Gold (1985).

This case study presents the ranking results of five commercial banks in Serbia, based on objective criteria. These criteria and their sub-criteria, adopted from Yeh (1996) and Hunjak and Jakocevic (2001), are shown in Table 1.

Weights of criteria, sub-criteria and the resulting weights, obtained on the basis of pairwise comparisons, are shown in Table 2. Due to limited space, the calculation procedure is omitted.

Ratings, i.e. performance ratings, of the considered banks, in relation to selected evaluation criteria, are shown in Table 3. These ratings are calculated based on data available on the web sites of the considered banks, i.e. financial reports for 2011 year, and data available on the website of the National Bank of Serbia.

Table 1. Quantitative criteria for bank performance determination

Criteria	Sub-criteria	Definitions
Liquidity (L)	L_1	Cash and cash equivalent + cash due from financial institutions / total deposits
	L_2	Total loans / total deposits
	L_3	Net cash flow from operating activities / total cash flow
Efficiency (E)	E_1	Operating cost / operating income
	E_2	Provisions for loans / net interest income
	E_3	Operating income / total number of employees
Profitability (P)	P_1	Profit before taxes / equity
	P_2	Profit before taxes / asset
	P_3	Profit before taxes / operating income
Capital adequacy (C)	C_1	Total liabilities / equity
	C_2	Equity / loans
	C_3	Total deposits / equity
	C_4	Capital adequacy ratio

Table 2. Relative weights of evaluation criteria

Criteria	w_c	Sub-criteria	w_{sc}	w_j
Liquidity (L)	0.375	L_1	0.429	0.161
		L_2	0.143	0.054
		L_3	0.429	0.161
Efficiency (E)	0.125	E_1	0.637	0.080
		E_2	0.258	0.032
		E_3	0.105	0.013
Profitability (P)	0.125	P_1	0.309	0.039
		P_2	0.582	0.073
		P_3	0.109	0.014
Capital adequacy (C)	0.375	C_1	0.217	0.081
		C_2	0.125	0.047
		C_3	0.165	0.062
		C_4	0.494	0.185

different alternatives as the best ranked. It might be a little confusing.

The obtained rankings orders, shown in the column VII of Table 4, also look confusing. By applying the same MCDM method and various normalization procedures, different ranking orders are obtained.

In order to resolve doubts about the best ranked alternative, ranking of banks was again performed using various MCDM methods. Obtained ranking results are shown in Table 5.

Due to easier comparison, in Table 5 are repeated results obtained by the SAW method used with Max and MaxMin normalization procedures.

Table 3. Initial decision matrix – banks' performances and criteria weights

Criteria and sub-criteria		w_i	Opt.	Alternatives (Banks)				
				B_1	B_2	B_3	B_4	B_5
L	L_1	0.161	max	2.50	1.47	1.31	1.34	1.57
	L_2	0.054	max	0.76	1.02	1.36	1.06	1.50
	L_3	0.161	max	0.26	0.29	0.18	0.18	0.24
E	E_1	0.080	min	0.49	0.28	0.43	0.43	0.44
	E_2	0.032	min	0.18	0.22	0.01	0.16	0.13
	E_3	0.013	max	5.01	6.51	12.65	24.58	12.19
P	P_1	0.039	max	0.012	0.016	0.026	0.043	0.002
	P_2	0.073	max	0.110	0.101	0.230	0.220	0.010
	P_3	0.014	max	0.179	0.225	0.338	0.527	0.038
C	C_1	0.081	min	5.36	2.69	4.20	2.20	3.57
	C_2	0.047	max	0.26	0.48	0.28	0.45	0.34
	C_3	0.062	min	4.97	2.02	2.57	2.06	1.91
	C_4	0.185	max	18.70	29.00	17.10	32.00	25.90

Note: Table 3 does not contain information on all banks which operate in Serbia. This table contains only performance ratings for some characteristic bank.

The ranking of banks was started using SAW method. The results of ranking banks obtained using SAW method and various normalization procedures are shown in Table 4.

Based on data from Table 4, it can be determined that SAW method, used with various normalization procedures, gave

From Tables 4 and 5 can be seen that there is a certain similarity in results obtained by using so-called performance-based methods, such as ARAS, COPRAS, MOORA(RS) and SAW method used with Max normalization procedure.

Table 4. Ranking results obtained using SAW method and various normalization procedures

Banks / Normalization methods		B_1	B_2	B_3	B_4	B_5	Best ranked	Ranking orders[1]
		I	II	III	IV	V	VI	VII
Max method	Q_i	0.623	0.768	0.643	0.780	0.648	B_4	$B_4 \succ B_2 \succ B_5$
	Rank	5	2	4	**1**	3		
Sum method	Q_i	0.328	0.369	0.345	0.384	0.338	B_4	$B_4 \succ B_2 \succ B_3$
	Rank	5	2	3	**1**	4		
Vector normalization	Q_i	0.413	0.500	0.442	0.524	0.438	B_4	$B_4 \succ B_2 \succ B_3$
	Rank	5	2	3	**1**	4		
Max-Min method	Q_i	0.350	0.653	0.290	0.558	0.448	B_2	$B_2 \succ B_4 \succ B_5$
	Rank	4	**1**	5	2	3		

[1]Ranking orders of three best ranked alternatives

Table 5. Ranking results obtained using various MCDM methods

Banks		B_1	B_2	B_3	B_4	B_5	Best ranke d	Ranking orders
Methods		I	II	III	IV	V	VI	VII
SAW (Max)	Q_i	0.623	0.768	0.643	0.780	0.648	B_4	$B_4 \succ B_2 \succ B_5$
	Rank	5	2	4	**1**	3		
ARAS	Q_i	0.728	0.895	0.856	0.937	0.747	B_4	$B_4 \succ B_2 \succ B_3$
	Rank	5	2	3	**1**	4		
COPRAS	Q_i	0.181	0.215	0.190	0.230	0.183	B_4	$B_4 \succ B_2 \succ B_3$
	Rank	5	2	3	**1**	4		
MOORA (RS)	Q_i	0.158	0.245	0.187	0.269	0.183	B_4	$B_4 \succ B_2 \succ B_3$
	Rank	5	2	3	**1**	4		
CP (p=1)	$L_{i,1}$	0.650	0.347	0.710	0.442	0.552	B_2	$B_2 \succ B_4 \succ B_5$
	Rank	4	**1**	5	2	3		
GRA (MaxMin)	G_i	0.704	0.491	0.755	0.589	0.581	B_2	$B_2 \succ B_5 \succ B_4$
	Rank	4	**1**	5	3	2		
MOORA (RP)		0.045	0.044	0.050	0.049	0.046	B_2	$B_2 \succ B_1 \succ B_5$
	Rank	2	**1**	5	4	3		
CP (p=2)	$L_{i,2}$	0.233	0.161	0.307	0.235	0.200	B_2	$B_2 \succ B_5 \succ B_1$
	Rank	3	**1**	5	4	2		
GRA (T)	G_i	0.882	1.080	0.870	1.163	1.026	B_3	$B_3 \succ B_1 \succ B_5$
	Rank	2	4	**1**	5	3		
VIKOR	Q_i	0.750	0.113	1.000	0.426	0.282	B_2, B_5	$B_2 \succ B_5 \succ B_4$
	Rank	4	**1**	5	3	2		
TOPSIS	C_i	0.441	0.541	0.418	0.573	0.409	B_4	$B_4 \succ B_2 \succ B_1$
	Rank	3	2	4	**1**	5		
SAW (MaxMin)		0.350	0.653	0.290	0.558	0.448	B_2	$B_2 \succ B_4 \succ B_5$
	Rank	4	**1**	5	2	3		

A deviation from the identified similarities in achieved results can be seen in the case of using GRA approach. In addition, in case of using CP, and p = 1, the deviation is more noticeable, and obtained results are the same as when the SAW method with MaxMin normalization procedure is used.

As is stated in subsections 2.5 and 2.6, the

GRA and CP methods are based on the idea that the best placed alternative has the smallest distance from the ideal point (solution) and therefore they can be placed in so-called distance-based approach methods.

If more detailed consider the MaxMin normalization procedure, which is shown by formula (7), we can notice that its use transforms SAW method into so-called distance-based approach methods, instead of the usual performance-based approach which is obtained using Max, Sum or Vector normalization procedures. Therefore, a weak correlation observed in the results obtained by the above mentioned method is quite expected.

The results obtained by using VIKOR also confirm above mentioned conclusions. However, in the case when VIKOR method is used, the second condition required in order to select the most acceptable alternative, ***C***1, is not satisfied, and therefore the set of compromise solutions is obtained, i.e. the set which contains alternatives B_2 and B_5.

From Table 5 can also be concluded that most of the distance-based methods stand B_2 as the most acceptable alternative. However, this is not so in the case of TOPSIS method application, one of most prominent methods. When applying TOPSIS method, the highest ranked alternative is B_4.

Data from columns VI and VII of Table 4 and Table 5 indicate that alternatives B_4 and B_2 are real candidates for the most acceptable alternative. However, on the basis of these data the most appropriate alternative cannot be determined for certain.

It is known that the criteria weights in MCDM models have significant influence on the selection of the most acceptable alternatives. It is also known that the used normalization procedures, as well as the aggregation procedure, have significant influence on selection of the best placed alternative.

Slightly confusing results obtained when using different MCDM methods in some way indicate that this is a characteristic case where mutual influence of the relative weights of criteria, applied normalization methods and aggregation procedures is particularly emphasized.

In order to make more realistic conclusions, below are considered influence of the criteria weights and impact of normalization procedures upon ranking order of considered alternatives.

3.2. Comparative Analysis: Examining the impact of criteria weights on ranking order

In order to make more objective conclusions, in this section we reconsider the previous example of ranking banks, but with modified weights of criteria.

In the first case (Case I), all criteria have the same weight, and the resulting weights of sub-criteria are calculated using the following formula:

$$w_j = \frac{1}{n_{sc}} w_c \ , \tag{55}$$

where w_j is resulting weight of j-th criterion, n_{sc} is the number of sub-criteria of c-th criterion, and w_c is weight of c-th criterion.

As shown in Table 6, criteria Liquidity, Efficiency and Profitability and Capital adequacy have the same weight, and it is 0.25. Criteria Liquidity, Efficiency and Profitability have three sub-criteria, and therefore they have the same weight, which

Table 6. Relative weights of evaluation criteria

Criteria	Weights of criteria w_c	Sub-criteria	Resulting weights of sub-criteria w_j
Liquidity (L)	0.25	L_1	0.083
		L_2	0.083
		L_3	0.083
Efficiency (E)	0.25	E_1	0.083
		E_2	0.083
		E_3	0.083
Profitability (P)	0.25	P_1	0.083
		P_2	0.083
		P_3	0.083
Capital adequacy (C)	0.25	C_1	0.063
		C_2	0.063
		C_3	0.063
		C_4	0.063

is 0.083. Criterion Capital adequacy has four sub-criteria, which is why their weight is 0.063.

In the second case (Case II), we start from demand that the resulting weights of all sub-criteria are the same, and also the following condition is satisfied:

$$\sum_{j=1}^{n} w_j = 1 \ . \qquad (56)$$

Therefore, the resulting weights of all sub-criteria have value 0.077, as shown in Table 7.

Comparative review of the best ranked alternatives, as well as ranking orders achieved in the case study, and scenarios I and II are shown in the Table 8.

From Table 8 can be concluded that changes in criteria weights may have impact on ranking order of alternatives, as shown in columns I and II, but it is not a strong rule, as shown in columns II and III.

Table 7. Relative weights of evaluation criteria

Criteria	Sub-criteria	Resulting weights of sub-criteria w_j
Liquidity (L)	L_1	0.077
	L_2	0.077
	L_3	0.077
Efficiency (E)	E_1	0.077
	E_2	0.077
	E_3	0.077
Profitability (P)	P_1	0.077
	P_2	0.077
	P_3	0.077
Capital adequacy (C)	C_1	0.077
	C_2	0.077
	C_3	0.077
	C_4	0.077

Table 8. Comparative review of the ranking orders obtained using different weights

	I	II	III
Method	Case study	Case I	Case II
SAW (Max)	$B_4 \succ B_2 \succ B_5$	$B_4 \succ B_3 \succ B_2$	$B_4 \succ B_3 \succ B_2$
SAW (Sum)	$B_4 \succ B_2 \succ B_3$	$B_4 \succ B_3 \succ B_2$	$B_4 \succ B_3 \succ B_2$
SAW (VN)	$B_4 \succ B_2 \succ B_3$	$B_4 \succ B_3 \succ B_2$	$B_4 \succ B_3 \succ B_2$
SAW (MaxMin)	$B_2 \succ B_4 \succ B_5$	$B_4 \succ B_2 \succ B_3$	$B_4 \succ B_2 \succ B_3$
ARAS	$B_4 \succ B_2 \succ B_3$	$B_3 \succ B_4 \succ B_2$	$B_3 \succ B_4 \succ B_2$
COPRAS	$B_4 \succ B_2 \succ B_3$	$B_4 \succ B_3 \succ B_2$	$B_4 \succ B_3 \succ B_2$
MOORA (RS)	$B_4 \succ B_2 \succ B_3$	$B_4 \succ B_3 \succ B_2$	$B_4 \succ B_3 \succ B_2$
CP (p=1)	$B_2 \succ B_4 \succ B_5$	$B_4 \succ B_2 \succ B_3$	$B_4 \succ B_2 \succ B_3$
GRA (MaxMin)	$B_2 \succ B_5 \succ B_4$	$B_5 \succ B_3 \succ B_2$	$B_5 \succ B_3 \succ B_2$
MOORA (RP)	$B_2 \succ B_1 \succ B_5$	$B_3 \succ B_4 \succ B_2$	$B_3 \succ B_4 \succ B_2$
CP (p=2)	$B_2 \succ B_5 \succ B_1$	$B_4 \succ B_2 \succ B_3$	$B_4 \succ B_2 \succ B_3$
GRA (T)	$B_3 \succ B_1 \succ B_5$	$B_3 \succ B_1 \succ B_5$	$B_3 \succ B_1 \succ B_5$
VIKOR	$B_2 \approx B_5 \succ B_4$	$B_4 \approx B_2 \succ B_3$	$B_4 \cong B_2 \succ B_3$
TOPSIS	$B_4 \succ B_2 \succ B_1$	$B_4 \succ B_3 \succ B_2$	$B_4 \succ B_3 \succ B_2$

3.3 Comparative Analysis: Examining the impact of distance metric and normalization procedure in TOPSIS method

As stated in section 2.8, when TOPSIS method is considered, ordinary TOPSIS method is based on the use of Vector normalization and Euclidean distance from the ideal and anti-ideal solution.

However, there are also some examples where TOPSIS method was used with other normalization procedures, especially in the case of fuzzy or grey extensions of TOPSIS method. In the literature the use of TOPSIS method was also considered with other metrics, such as city block distance.

In order to more accurately determine influence which normalization and aggregation procedures have, in this section are presented and discussed results of banks ranking which are obtained using some modified variants of TOPSIS method.

In column I of Table 9 are shown the results obtained by using ordinary TOPSIS method.

In column II of Table 9 are shown the results obtained by using a variant of TOPSIS method, where City block distance was used instead of Euclidean distance. In this case, replacement of distance metric has no impact on the best placed alternative, but it is reflecting on the ranking order of alternatives.

In columns III and IV, TOPSIS method was used with MaxMin normalization procedure. In column III are shown results when Euclidean distance was used, while in column IV when City block distance is used.

As can be seen from columns III and IV, the use of MaxMin normalization procedure had an impact on the best ranked alternative, i.e., alternative B_2 has become the best ranked alternative instead of alternative B_4. Unlike when vector normalization was used, the change of distance metrics had no

Table 9. Ranking results obtained using different variants of TOPSIS method

	Case Study							
	I		II		III		IV	
Normalization	Vector		Vector		MaxMin		MaxMin	
Distance metric	Euclidean		City block		Euclidean		City block	
Alternative	C_i	Rank	C_i	Rank	C_i	Rank	C_i	Rank
B_1	0.441	3	0.328	5	0.465	4	0.350	4
B_2	0.541	2	0.577	2	0.616	1	0.653	1
B_3	0.418	4	0.410	3	0.268	5	0.290	5
B_4	0.573	1	0.646	1	0.497	2	0.558	2
B_5	0.409	5	0.399	4	0.466	3	0.448	3
Best placed	B_4		B_4		B_2		B_2	
Ranking order	$B_4 \succ B_2 \succ B_1$		$B_4 \succ B_2 \succ B_3$		$B_2 \succ B_4 \succ B_5$		$B_2 \succ B_4 \succ B_5$	

influence upon ranking order of alternatives.

Table 10 shows the results obtained using different variants of TOPSIS method and weights from Table 7 (Case I).

Compared with the same columns of Table 9, the change of criteria weights have caused significant changes on the best placed alternative, as well as ranking orders of alternatives.

Table 11 shows the results obtained using different variants of TOPSIS method and weights from Table 7 (Case II).

Table 10. Ranking results obtained using different variants of TOPSIS method

	Case I							
	I		II		III		IV	
Normalization	Vector		Vector		MaxMin		MaxMin	
Distance metric	Euclidean		City block		Euclidean		City block	
Alternatives	C_i	Rank	C_i	Rank	C_i	Rank	C_i	Rank
B_1	0.291	5	0.237	5	0.340	5	0.249	5
B_2	0.387	3	0.436	3	0.506	2	0.534	2
B_3	0.599	2	0.565	2	0.486	3	0.468	3
B_4	0.704	1	0.750	1	0.579	1	0.651	1
B_5	0.312	4	0.317	4	0.412	4	0.391	4
Best placed	B_4		B_4		B_4		B_4	
Ranking order	$B_4 \succ B_3 \succ B_2$		$B_4 \succ B_3 \succ B_2$		$B_4 \succ B_2 \succ B_3$		$B_4 \succ B_2 \succ B_3$	

Table 11. Ranking results obtained using different variants of TOPSIS method

	Case II							
	I		II		III		IV	
Normalization	Vector		Vector		MaxMin		MaxMin	
Distance metric	Euclidean		City block		Euclidean		City block	
Alternatives	C_i	Rank	C_i	Rank	C_i	Rank	C_i	Rank
B_1	0.280	5	0.224	5	0.317	5	0.232	5
B_2	0.421	3	0.464	3	0.540	2	0.562	2
B_3	0.589	2	0.554	2	0.471	3	0.456	3
B_4	0.713	1	0.762	1	0.606	1	0.675	1
B_5	0.342	4	0.339	4	0.436	4	0.409	4
Best placed	B_4		B_4		B_4		B_4	
Ranking order	$B_4 \succ B_3 \succ B_2$		$B_4 \succ B_3 \succ B_2$		$B_4 \succ B_2 \succ B_3$		$B_4 \succ B_2 \succ B_3$	

Compared with the same columns of Table 10, small changes in criteria weights do not have impact on the best placed alternative, and alternatives ranking orders.

Table 12 shows the summary results of ranking alternatives, which are obtained on the basis of use of different normalization procedures and different distance metrics.

In many scientific and professional journals, a number of papers have been devoted to comparison of some MCDM methods. Although research devoted to development and the usage of Fuzzy and/or Grey MCDM methods are currently more actual, the problem of selection of the most appropriate MCDM method is also actual.

Table 12. Ranking results obtained using different variants of TOPSIS method

	I	II	III	IV
Normalization	Vector	Vector	MaxMin	MaxMin
Distance metric	Euclidean	City block	Euclidean	City block
Case Study	$B_4 \succ B_2 \succ B_1$	$B_4 \succ B_2 \succ B_3$	$B_2 \succ B_4 \succ B_5$	$B_2 \succ B_4 \succ B_5$
Case I	$B_4 \succ B_2 \succ B_3$	$B_4 \succ B_3 \succ B_2$	$B_4 \succ B_2 \succ B_3$	$B_4 \succ B_2 \succ B_3$
Case II	$B_4 \succ B_3 \succ B_2$	$B_4 \succ B_3 \succ B_2$	$B_4 \succ B_2 \succ B_3$	$B_4 \succ B_2 \succ B_3$

From the above table, it can be concluded that the use of different normalization procedures and different distance metrics may have influence to the selection of the best ranked alternative and ranking order of alternatives.

4. CONCLUSION

Example considered in Case Study and its variations clearly indicate that, under certain circumstances, the use of different MCDM methods sometimes highlights different alternatives as the most appropriate alternative, as well as gives the different ranking order of alternatives.

Different aggregation procedures and different normalization procedures sometimes lead to the selection of different most acceptable alternatives.

At the same time, different relative weights of criteria, used in the decision-making model, can also have a significant impact on the selection of most appropriate alternatives, as well as ranking orders.

In this paper, we only highlighted some reasons which lead to different results, and indicate that different results obtained by different MCDM methods are not just a random event, but rather reality. We also emphasize that considered MCDM methods have their own specifics and advantages, which is why the choice of MCDM method may be a rather complex problem.

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УПОРЕДНА АНАЛИЗА НЕКИХ ЗНАЧАЈНИХ МЕТОДА ВИШЕКРИТЕРИЈУМСКОГ ОДЛУЧИВАЊА: ПРИМЕР РАНГИРАЊА СРПСКИХ БАНАКА

Драгиша Станујкић, Бојан Ђорђевић и Мира ђорђевић

Извод

У литератури су предложене бројне методе вишекритеријумског одлучивања. Такође је публикован и значајан број радова у којима је извршено поређење њихових карактеристика и перформанси. Међутим, коначан одговори на питања: која метода је најприкладнија и која метода је најефективнија су и даље актуелни. Због тога је у овом раду разматрана примена неких значајних метода вишекритеријумског одлучивања, на примеру рангирања српских банака. Циљ овог рада ипак није био одређивање најприкладније методе вишектитеријумског одлучивања за рангирање банака. Основни циљ овог рада је да се укаже на то да се коришћењем различитих метода вишекритеријумског одлучивања у појединим случајевима могу остварити различити редоследи рангираних алтернатива и такође истакне да различити резултати остварени применом појединих метода нису само случајност, већ реалност.

Кључне речи: “MCDM, SAW, MOORA, GRA, CP, VIKOR, TOPSIS”

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