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Improved OCRA Method Based on the Use of Interval Grey Numbers

Dragisa Stanujkic[1*], Edmundas Kazimieras Zavadskas[2], Sifeng Liu[3,4], Darjan Karabasevic[5], Gabrijela Popovic[1]

1. Faculty of Management in Zajecar, John Naisbitt University, Park Suma Kraljevica bb, Zajecar 19000, Serbia.
2. Research Institute of Smart Building Technologies, Civil Engineering Faculty Vilnius Gediminas Technical University, Saulėtekio al. 11, Vilnius 10221, Lithuania.
3. College of Economics and Management, Nanjing University of Aeronautics and Astronautics, Nanjing 211106, P.R. China.
4. Institute for Grey Systems Studies, Nanjing University of Aeronautics and Astronautics, Nanjing 211106, P.R. China.
5. Faculty of Applied Management, Economics and Finance, University Business Academy in Novi Sad, Jevrejska 24, Belgrade 11000, Serbia

Abstract

Multiple Criteria Decision Making (MCDM) denotes the selection of the alternatives based on a set of, often conflicting, criteria. As a result of using it for solving a large number of decision-making problems, a number of MCDM methods have been proposed. Some of these methods are further adapted to use grey numbers, with the aim of ensuring their broader usage. The Operational Competitiveness Rating (OCRA) method is a less frequently used MCDM method, for which the grey extension has not been proposed yet. Therefore, an improved OCRA method is proposed in this paper. In the proposed approach, the ordinary OCRA method is adapted for the purpose of enabling the use of grey numbers, which has enabled its usage for solving decision-making problems associated with uncertain and partially known information. In addition to this, in the improved OCRA method the original normalization procedure has been replaced by a new one. Finally, the usability and effectiveness of the proposed approach are checked on two numerical illustrations. The first is taken from the literature. The ranking results obtained by using the improved OCRA method are the same as the results obtained by using two prominent MCDM methods, which confirms the usability of the proposed approach. In the second one, the usability and efficiency of the improved OCRA method are verified in the case of the selection of the best capital investment project.

Keywords: Multiple Criteria Decision Making; MCDM; OCRA; Improved OCRA; Interval Grey Numbers

[*] ***Corresponding Author***: *Dragisa STANUJKIC, Faculty of Management in Zajecar, John Naisbitt University, Park Suma Kraljevica b.b., Zajecar 19000, Serbia; Email: dragisa.stanujkic@fmz.edu.rs*

1. Introduction

Multiple Criteria Decision Making (MCDM) denotes the selection and/or ranking of the alternatives based on a set of, often conflicting, criteria. As the results of the significant number of the studies conducted in this field, a number of prominent MCDM methods have been proposed, such as: Simple Additive Weighting (SAW)[1,2], Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS)[3], Preference Ranking Organization Method for Enrichment Evaluations (PROMETHEE)[4], the ELimination and Choice Expressing Reality (ELECTRE)[5] family and Multi-criteria Optimization and Compromise Solution (VIKOR)[6].

Beside the above-mentioned, there are a number of significantly less frequently used MCDM methods, such as: Organization, Rangement Et Synthese De Donnes Relationnelles (ORESTE)[7], Operational Competitiveness Rating (OCRA)[8], Closed Procedures near Reference Situations (ZAPROS)[9], Interactive and Multi-criteria Decision Making (TODIM)[10,11], Kemeny Median Indicator Rank Accordance (KEMIRA)[12], Evaluation Based on Distance from Average Solution (EDAS)[13] and so on.

Although OCRA can be classified as a rarely used MCDM method, it was successfully used for solving various decision-making problems in various areas, such as: performance and efficiency measurement[14]-[22], manufacturing[23,24,25,26], the location selection[27], the material selection[28,29], the hotel selection[30] and so on. The above, so-called classical, MCDM methods are mainly based on the use of crisp numbers. However, a significant number of real decision-making problems are accompanied by some kinds of predictions and uncertainties, for which reason the classical MCDM methods are not suitable for solving them.

Significant progress in terms of solving such problems was provided after Zadeh[31] and Deng[32] had proposed the fuzzy set theory and the grey set theory, respectively. Based on the fuzzy and the grey set theories, many ordinary MCDM methods have further been extended with the aim of applying fuzzy or grey numbers, i.e. their usage is ensured for solving a much larger number of real decision-making problems.

The Grey System Theory is identified in many studies as an effective methodology that can be used to solve decision-making problems with partially known information. Therefore, many ordinary MCDM methods are extended for the purpose of using interval grey numbers.

The following extensions can be mentioned as some of these: Grey TOPSIS[33,34,35], COPRAS-G[36], SAW-G[37,35], ARAS-G[38], the grey extension of the LINMAP[39] method, the grey extension of the MOORA[40,41] method, Grey AHP[42], Grey Compromise Programming[43] and so on.

The above-mentioned grey extensions are successfully used for solving a large number of different problems, such as: the supplier selection[44,45], air traffic management[46], the supply chain performance benchmarking[47], the selection of the inside thermal insulation[48], the assessment of the structural systems of high-rise buildings[49], the social media platform selection[50], the market segment evaluation[51], the building foundation alternatives selection[52], the robot selection[53] and so on.

In order to enable the use of the OCRA methods for solving a much larger number of decision-making problems, i.e. problems placed in imprecise and uncertain environments, the grey extension of the OCRA method is proposed in this paper.

Therefore, the remaining part of the paper is organized as follows: In Section 2, some basic elements of the Grey System Theory are presented. In Section 3, the OCRA method is demonstrated. In Section 4, an extension of the OCRA method adapted for the purpose of using interval grey numbers is discussed. In section 5, numerical illustrations are considered in order to verify the proposed approach. Finally, Section 6 presents the conclusions.

2. Grey Numbers and Their Operations

In the Grey System Theory, several types of grey numbers are proposed, of which black, white and interval grey numbers are emphasized here.

Definition 1 A grey number, denoted as $\otimes x$, is such a number whose exact value is unknown, but the range within which the value lies is known. A grey number with the known upper, $\bar{x}$, and the lower, $\underline{x}$, bounds, but the unknown distribution information for x is called the interval grey number[54,55]:

$$\otimes x \in [\underline{x}, \bar{x}] = [x' \in x \mid \underline{x} \le x' \le \bar{x}]. \tag{1}$$

Definition 2 The distance between the bounds of an interval grey number $l(\otimes x) = \bar{x} - \underline{x}$ is called the length of the information field of the grey number $\otimes x$, or more shortly, the length of the grey number. When the length of an interval grey number increases and the bounds tend to infinity, $\underline{x} \to -\infty$ and $\bar{x} \to +\infty$, then the interval grey number tends to become a black number. In contrast to the previous one, when the length decreases, then the interval grey number tends to become a white number; finally, when the upper and the lower bounds are equal, $\underline{x} = \bar{x}$, such an interval grey number becomes a white (crisp) number[56].

Definition 3 ***The basic operations of interval grey numbers***. Let $\otimes x_1 \in [\underline{x}_1,\ \bar{x}_1]$, and $\otimes x_2 \in [\underline{x}_2,\ \bar{x}_2]$ be the two interval grey numbers. The basic operations of the interval grey numbers $\otimes x_1$ and $\otimes x_2$ are defined as follows[55,57]:

$$\otimes x_1 + \otimes x_2 \in [\underline{x}_1 + \underline{x}_2,\ \bar{x}_1 + \bar{x}_2], \tag{2}$$

$$\otimes x_1 - \otimes x_2 \in [\underline{x}_1 - \bar{x}_2,\ \bar{x}_1 - \underline{x}_2], \tag{3}$$

$$\otimes x_1 \times \otimes x_2 \in [\min\{\underline{x}_1\underline{x}_2, \underline{x}_1\bar{x}_2, \bar{x}_1\underline{x}_2, \bar{x}_1\bar{x}_2\},\ \max\{\underline{x}_1\underline{x}_2, \underline{x}_1\bar{x}_2, \bar{x}_1\underline{x}_2, \bar{x}_1\bar{x}_2\}], \tag{4}$$

$$\otimes x_1 \div \otimes x_2 \in [\min\left\{\frac{\underline{x}_1}{\underline{x}_2}, \frac{\underline{x}_1}{\bar{x}_2}, \frac{\bar{x}_1}{\underline{x}_2}, \frac{\bar{x}_1}{\bar{x}_2}\right\},\ \max\left\{\frac{\underline{x}_1}{\underline{x}_2}, \frac{\underline{x}_1}{\bar{x}_2}, \frac{\bar{x}_1}{\underline{x}_2}, \frac{\bar{x}_1}{\bar{x}_2}\right\}], \tag{5}$$

$$k \otimes x_1 \in [k\underline{x}_1, k\bar{x}_1]. \tag{6}$$

Here, k is a positive real number and for Eq. (5) $\underline{x}_2 \ne 0$ and $\bar{x}_2 \ne 0$.

Definition 4 ***The whitened value***. The whitened value of an interval grey number $x_{(\lambda)}$ is a crisp number whose possible values lie between the upper and the lower bounds of the interval grey number $\otimes x$. For the given interval grey number $\otimes x \in [\underline{x}, \bar{x}]$, the whitened value $x_{(\lambda)}$ can be determined as follows[55,57]:

$$x_{(\lambda)} = (1-\lambda)\ \underline{x} + \lambda\ \bar{x}, \tag{7}$$

where λ denotes the whitening coefficient and $\lambda \in [0,1]$. In the particular case, when $\lambda = 0.5$, the whitened value becomes the mean of the interval grey number, as follows:

$$x_{(\lambda=0.5)} = \frac{1}{2}(\underline{x} + \overline{x}). \tag{8}$$

3. Operational Competitiveness Rating Method

As previously mentioned, the OCRA method was proposed by Parkan[8] and further developed by Parkan and Wu[58,59,60].

This method was initially developed in order to measure the relative performances of a set of production units, where resources are consumed to create value-added outputs [28]. Later, this method was used to solve other various multiple criteria decision-making problems.

Parkan and Wu[58] state that this method applies an intuitive approach to incorporating the decision maker's preferences for the relative importance of the criteria. According to Chatterjee and Chakraborty[28], the main advantage of the OCRA method is that it can deal with those MCDM situations in which the relative weights of the criteria are dependent on the alternatives and different weight distributions are assigned to the criteria for different alternatives, whereas some of the criteria are not applicable to all the alternatives, either.

The main idea of the OCRA method is to perform the independent evaluation of alternatives with respect to benefit and cost criteria, and finally to combine these two aggregate ratings so as to obtain competitiveness ratings, which helps decision makers not to lose information during the decision-making process [61].

Based on Parkan and Wu[60], Chatterjee and Chakraborty[28] and Liu *et al.*[62], the computational procedure of the improved OCRA method can be described through the following steps:

Step 1 Calculate the aggregate performance ratings for the cost criteria, as follows:

$$\bar{I}_i = \sum_{j \in \Omega_{\min}} w_j \frac{\max_j x_{ij} - x_{ij}}{\min_j x_{ij}} \notin [-1,1], \tag{9}$$

where $\bar{I}_i$ denotes the aggregate performance rating of the alternative i, obtained on the basis of the cost (Input) criteria, x_{ij} denotes the performance rating of the alternative i with respect to the criterion j and $\Omega_{\min}$ is the set of the cost (minimization) criteria.

Based on *Liu et al.* [62] Eq. (9) could be replaced with the following one:

$$\bar{I}_i = \sum_{j \in \Omega_{\min}} w_j \frac{\max_j x_{ij} - x_{ij}}{\max_j x_{ij} - \min_j x_{ij}} \in [-1,1]. \tag{10}$$

Step 2 Calculate the linear performance ratings for the cost criteria, as follows:

$$\bar{\bar{I}}_i = \bar{I}_i - \min_i \bar{I}_i, \tag{11}$$

where $\bar{\bar{I}}_i$ denotes the linear performance rating of the alternative i, obtained on the basis of the cost criteria.

The linear scaling in the OCRA method is made with the aim of assigning zero ratings to the least preferable alternative.

Step 3 Calculate the aggregate performance ratings with respect to the benefit criteria, as follows:

$$\overline{O}_i = \sum_{j \in \Omega_{\max}} w_j \frac{x_{ij} - \min_j x_{ij}}{\min_j x_{ij}} \notin [-1,1], \tag{12}$$

where $\overline{O_i}$ denotes the aggregate performance rating of the alternative i, obtained on the basis of the benefit (Output) criteria, and $\Omega_{\max}$ denotes the set of the benefit (maximization) criteria.

Based on *Liu et al.* [62] Eq. (11) could be replaced with the following equation:

$$\overline{O_i} = \sum_{j\in\Omega_{\max}} w_j \frac{x_{ij} - \min_j x_{ij}}{\max_j x_{ij} - \min_j x_{ij}} \in [-1,1]. \qquad (13)$$

Step 4 Calculate the linear performance ratings for the benefit criteria, as follows:

$$\overline{\overline{O_i}} = \overline{O_i} - \min_i \overline{O_i}, \qquad (14)$$

where $\overline{\overline{O_i}}$ denotes the linear performance rating of the alternative i, obtained on the basis of the benefit criteria.

Step 5 Calculate the overall performance ratings, as follows:

$$P_i = \overline{\overline{I_i}} + \overline{\overline{O_i}} - \min(\overline{\overline{I_i}} + \overline{\overline{O_i}}), \qquad (15)$$

where P_i denotes the overall performance rating of the alternative i.

Step 6 Select the most appropriate alternative. Based on the OCRA method, the alternative with the highest value of P_i is the most appropriate.

The computational procedure of the OCRA method is based on the use of the distance to the least preferable performances of the criteria, i.e. $\max_j x_{ij} - x_{ij}$ for the cost criteria, and $x_{ij} - \min_j x_{ij}$ for the benefit criteria. That indicates a certain similarity to the prominent TOPSIS and VIKOR methods.

However, the OCRA method has its particularities; the specific normalization procedure shown in Eqs (9) and (11) can be mentioned as one the most significant. Contrary to commonly used normalization procedures, the normalization procedure used in the ordinary OCRA method does not enable the values of normalized performance ratings to always belong to [0,1], whereas in particular cases these values can be greater than that one.

An improvement of the OCRA method is made by replacing Eqs (9) and (12) with Eqs (10) and (13), thus enabling the normalized performance ratings to always belong to [0,1].

Due to the particularities of the OCRA method, the comparison of the results obtained by using TOPSIS, VIKOR, SAW and OCRA is shown in Appendix A.

4. Improved Operational Competitiveness Rating Method

In order to enable the usage of the OCRA method for solving MCDM problems accompanied by predictions and uncertainties, an extension of the OCRA method, adapted for the usage of interval grey numbers, is proposed in this section.

The computational procedure of the proposed grey extension of the OCRA method can be shown as follows:

Step 1 Calculate the grey aggregate performance ratings for the cost criteria, as follows:

$$\otimes \bar{I}_i = \sum_{j\in\Omega_{\min}} w_j \frac{\max_j \otimes x_{ij} - \otimes x_{ij}}{\max_j \otimes x_{ij} - \min_j \otimes x_{ij}}, \qquad (16)$$

where $\otimes \bar{I}_i$ denotes the grey aggregate performance rating of the alternative i, obtained on the basis of the cost criteria, $\otimes x_{ij} \in [x'_{ij}, x''_{ij}]$ denotes the grey performance rating of the alternative i with respect to the criterion j, $\max_j \otimes x_{ij} \in [\max_j x'_{ij}, \max_j x''_{ij}]$ and $\min_j \otimes x_{ij} \in [\min_j x'_{ij}, \min_j x''_{ij}]$.

On the basis of the operations of interval grey numbers, Eq. (16) can also be shown as follows:

$$\otimes \bar{I}_i = \sum_{j\in\Omega_{\min}} w_j \frac{[\max_j x'_{ij}, \max_j x''_{ij}] - [x'_{ij}, x''_{ij}]}{[\max_j x'_{ij}, \max_j x''_{ij}] - [\min_j x'_{ij}, \min_j x''_{ij}]}, \tag{16a}$$

or as:

$$\otimes \bar{I}_i = \sum_{j\in\Omega_{\min}} w_j \frac{[\max_j x'_{ij} - x''_{ij}, \max_j x''_{ij} - x'_{ij}]}{[\max_j x'_{ij} - \min_j x'', \max_j x''_{ij} - \min_j x'_{ij}]}. \tag{16b}$$

Step 2 Calculate the grey linear performance ratings for the cost criteria, as follows:

$$\otimes \bar{\bar{I}}_i = \otimes \bar{I}_i - \min_i \otimes \bar{I}_i, \tag{17}$$

where $\otimes \bar{\bar{I}}_i \in [\bar{\bar{I}}'_i, \bar{\bar{I}}''_i]$ denotes the grey linear performance ratings of the alternative i, obtained on the basis of the cost criteria, and $\min_i \otimes \bar{I}_i \in [\min_i \bar{I}'_i, \min_i \bar{I}''_i]$.

Eq. (17) can also be written as follows:

$$\otimes \bar{\bar{I}}_i \in [\bar{I}'_i - \min_i \bar{I}''_i, \bar{I}''_i - \min_i \bar{I}'_i]. \tag{17a}$$

Step 3 Calculate the grey aggregate performance ratings for the benefit criteria in the following manner:

$$\otimes \bar{O}_i = \sum_{j\in\Omega_{\max}} w_j \frac{\otimes x_{ij} - \min_j \otimes x_{ij}}{\max_j \otimes x_{ij} - \min_j \otimes x_{ij}}, \tag{18}$$

where $\otimes \bar{O}_i \in [\bar{O}'_i, \bar{O}''_i]$ denotes the grey aggregate performance rating of the alternative i.

Eq. (18) can also be shown as follows:

$$\otimes \bar{O}_i = \sum_{j\in\Omega_{\max}} w_j \frac{[x'_{ij}, x''_{ij}] - [\min_j x'_{ij}, \min_j x''_{ij}]}{[\max_j x'_{ij}, \max_j x''_{ij}] - [\min_j x'_{ij}, \min_j x''_{ij}]}, \tag{18a}$$

or as:

$$\otimes \bar{O}_i = \sum_{j\in\Omega_{\max}} w_j \frac{[x'_{ij} - \min_j x'', x''_{ij} - \min_j x'_{ij}]}{[\max_j x'_{ij} - \min_j x'', \max_j x''_{ij} - \min_j x'_{ij}]}. \tag{18b}$$

Step 4 Calculate the linear performance ratings for the benefit criteria, as follows:

$$\otimes \bar{\bar{O}}_i = \otimes \bar{O}_i - \min_i \otimes \bar{O}_i, \tag{19}$$

where $\otimes \bar{\bar{O}}_i \in [\bar{\bar{O}}'_i, \bar{\bar{O}}''_i]$ denotes the grey linear performance ratings of the alternative i, obtained on the basis of the benefit criteria, and $\min_i \otimes \bar{O}_i \in [\min_i \bar{O}'_i, \min_i \bar{O}''_i]$.

Eq. (19) can also be shown as follows:

$$\otimes \bar{\bar{O}}_i \in [\bar{O}'_i - \min_i \bar{O}''_i, \bar{O}''_i - \min_i \bar{O}'_i]. \tag{19a}$$

Step 5 Calculate the overall grey performance ratings. The overall performance rating for each alternative could be calculated as follows:

$$\otimes P_i = \otimes \overline{\overline{I}}_i + \otimes \overline{\overline{O}}_i - \min(\otimes \overline{\overline{I}}_i + \otimes \overline{\overline{O}}_i)\,. \tag{20}$$

Eq. (20) can also be shown as follows:

$$\otimes P_i \in [\overline{\overline{I'}}_i + \overline{\overline{O'}}_i - \min_i(\overline{\overline{I''}}_i + \overline{\overline{O''}}_i), \overline{\overline{I''}}_i + \overline{\overline{O''}}_i - \min_i(\overline{\overline{I'}}_i + \overline{\overline{O'}}_i)]\,. \tag{20a}$$

Step 6. **Select the most appropriate alternative.** Based on the use of the improved OCRA method, the overall grey performance ratings $\otimes P_i$ should be transformed into the overall crisp performance ratings P_i before the ranking, which can be done by applying Eq. (7).

In this way, the decision makers involved in the evaluation can consider scenarios ranging from pessimistic to optimistic by varying the values of the coefficient λ.

5. Numerical Illustrations

In this section, two numerical illustrations are considered in order to explain the proposed methodology in detail and confirm its usability. The first was taken from the literature, whereas the second was particularly prepared for the purpose of this manuscript.

5.1. The First Numerical Illustration

In the sub-second numerical illustration, adopted from Zavadskas *et al.*[37], the selection of the contractors for the construction of prefabricated wooden shield-shaped houses is considered. The selected criteria, the criteria weights and the performance ratings are shown in Table 1.

Table 1 The initial grey decision-making matrix

	Criteria											
	Experience of executives		Number of constructed houses		Turnover		Number of executives		Market share		Production method	
	years		units		10^6€		persons		portion of sales		points	
	max		*max*		*max*		*min*		*max*		*max*	
w_i	0.22		0.26		0.11		0.09		0.15		0.17	
	C_1		C_2		C_3		C_4		C_5		C_5	
	x'	x''	x'	x''	x'	x''	x'	x''	x'	x''	x'	x''
A_1	11	15	10	15	3.30	4.50	35	48	0.152	0.203	1	2
A_2	10	14	7	13	2.54	3.68	40	58	0.111	0.162	1	2
A_3	14	18	5	9	1.95	2.46	42	53	0.079	0.121	1	3
A_4	12	16	1	4	0.42	1.73	15	63	0.010	0.054	1	2
A_5	6	10	2	9	0.62	2.67	10	46	0.120	0.122	1	2

The computational data obtained by using the improved OCRA method are shown in Table 2.

Table 2 The computational data obtained by using improved OCRA

	$\otimes \overline{I}_i$		$\otimes \overline{\overline{I}}_i$		$\otimes \overline{O}_i$		$\otimes \overline{\overline{O}}_i$		$\otimes P_i$	
Alternatives	x'	x''	x'	x''	x'	x''	x'	x''	x'	x''
A_1	-0.63	0.14	0.08	1.85	-0.72	1.33	-0.93	2.36	-4.50	6.48
A_2	-0.52	0.36	-0.05	1.59	-0.61	1.55	-1.06	2.09	-4.52	6.44
A_3	-0.47	0.25	-0.22	1.49	-0.56	1.44	-1.23	1.99	-4.65	6.23
A_4	-1.08	0.47	-0.42	1.01	-1.17	1.67	-1.43	1.51	-5.45	5.97
A_5	-1.19	0.09	-0.50	1.07	-1.28	1.28	-1.51	1.57	-5.65	5.65

The grey aggregate and grey linear performance ratings for the cost criteria are calculated by using Eqs (16) and (17), whereas the grey aggregate and grey linear

performance ratings for the cost criteria are calculated by using Eqs (18) and (19). Finally, the overall grey performance ratings are calculated by using Eq. (20).
The ranking order of the considered alternatives, obtained by using Eq. (7) and $\lambda = 0.5$, are shown in Table 3.

Table 3 The ranking orders of the considered alternatives

Alternatives	P_i	Rank
A_1	0.99	1
A_2	0.96	2
A_3	0.79	3
A_4	0.26	4
A_5	0.00	5

Finally, in Table 4, the comparison of the ranking results obtained by the improved OCRA method and the results obtained in Zavadskas *et al*.[37] are shown.

Table 4 The comparison of the ranking orders obtained by using COPRAS-G and improved OCRA

Alternatives	Zavadskas *et al.* [37] SAW-G	Zavadskas *et al.* [37] TOPSIS-G	Improved OCRA
	Rank	Rank	Rank
A_1	1	1	1
A_2	2	2	2
A_3	3	3	3
A_4	5	5	4
A_5	4	4	5

According to the comparison shown in Table 4, the ranking orders of the considered alternatives obtained by the proposed improvement of the OCRA method are similar to the ranking orders obtained in Zavadskas *et al*.[37], which confirms the usability of the proposed improvement of the OCRA method.

It is not easy to say that a certain MCDM method is dominant in relation to another because each one of them has its own computation and ranking logic, as well as certain specificities. The improved OCRA method enables the usage of grey numbers, for which reason it can be used for solving a larger number of complex decision-making problems, while its computational and ranking procedures remain understandable and relatively easy to use.

5. 2 The Second Numerical Illustration

In this numerical illustration, the improved OCRA method is used in order to choose the best capital investment project, or more precisely, to enable the selection of investment in the most appropriate type of hotels in a ski center. The usage of the Grey OCRA method has been considered in the case of the ski center Besna Kobila, an almost unknown ski center in southeastern Serbia, near the frontier of Serbia, Bulgaria and FYRoM (Macedonia), which could be very attractive in the future. Five types of hotels have been evaluated on the basis of the following four criteria:

- Number of units (C_1),
- Surface of accommodation units (C_2),
- Capital investments costs (C_3), and
- Annual operating income per accommodation unit (C_4).

The available alternatives and their ratings, adopted from the business plan for the tourism destination Besna Kobila, are accounted for in Table 5. The weights of the criteria, obtained on the basis of the three experts' opinions by using the SWARA[63] method, are also given in Table 5.

Table 5 Estimated ratings for accommodation units at the Ski Center Besna Kobila

Alternatives		C_1	C_2 m^2	C_3 €/m^2	C_4 €
	Optimization	*max*	*max*	*min*	*max*
Destination hotel	A_1	100	30-80	900-950	25000-30000
Apartments	A_2	100	60-90	800-850	15000-20000
Condotel	A_3	100	40-80	800-900	15000-20000
Townhouse	A_4	25	70-90	850-950	10000-20000
Chalet	A_5	10	100-130	900-1000	20000-35000

Source: Available at: http://mtt.gov.rs/download/sektor-za-turizam/master-planovi/master_plan_besna_kobila_finalno.pdf (In Serbian, accessed the last time: 16th Dec. 2016).

The computational details obtained by using the improved OCRA method based on the use of interval grey numbers, as well as the overall performances and the ranking order of the evaluated alternatives, are demonstrated in Tables 6 and 7.

Table 6 The computational details obtained by using Improved OCRA

Alternatives	$\otimes\bar{I}_i$		$\otimes\bar{\bar{I}}_i$		$\otimes\bar{O}_i$		$\otimes\bar{\bar{O}}_i$		$\otimes P_i$	
	x'	x''	x'	x''	x'	x''	x'	x''	x'	x''
A_1	-0.32	-0.32	0.32	0.32	-0.12	-0.12	0.51	0.51	0.51	0.51
A_2	0.08	0.08	0.71	0.71	-0.22	-0.22	0.41	0.41	0.81	0.81
A_3	0.00	0.00	0.63	0.63	-0.39	-0.39	0.24	0.24	0.56	0.56
A_4	-0.32	-0.32	0.32	0.32	-0.63	-0.63	0.00	0.00	0.00	0.00
A_5	-0.63	-0.63	0.00	0.00	0.03	0.03	0.67	0.67	0.35	0.35

Table 7 The ranking orders of the considered alternatives

Alternatives	P_i	Rank
A_1	0.51	3
A_2	0.81	1
A_3	0.56	2
A_4	0.00	5
A_5	0.35	4

As can be seen from Table 7, the best investment alternative for the Ski Center Besna Kobila is investment in Apartments.

6. Conclusion

This paper presents an improvement of the OCRA method based on the use of interval grey numbers.

On the basis of the proposed improvement, the OCRA method can be used more efficiently for solving a larger number of complex real-world decision-making problems, especially those associated with uncertainty and partially known information; so, it can be applied in many fields for the purpose of analysis, modelling and forecasting.

Finally, the usability and effectiveness of the proposed approach are checked on the two numerical illustrations. The first was taken from the literature. The ranking results obtained by using the improved OCRA method are the same as the results obtained by using the two prominent MCDM methods, which confirms the usability of the proposed approach. In the second, the usability and efficiency of the improved OCRA method are verified in the case of the selection of the best capital investment project.

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