

Article

A New Grey Approach for Using SWARA and PIPRECIA Methods in a Group Decision-Making Environment

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Abstract: The environment in which the decision-making process takes place is often characterized by uncertainty and vagueness and, because of that, sometimes it is very hard to express the criteria weights with crisp numbers. Therefore, the application of the Grey System Theory, i.e., grey numbers, in this case, is very convenient when it comes to determination of the criteria weights with partially known information. Besides, the criteria weights have a significant role in the multiple criteria decision-making process. Many ordinary multiple criteria decision-making methods are adapted for using grey numbers, and this is the case in this article as well. A new grey extension of the certain multiple criteria decision-making methods for the determination of the criteria weights is proposed. Therefore, the article aims to propose a new extension of the Step-wise Weight Assessment Ratio Analysis (SWARA) and Pivot Pairwise Relative Criteria Importance Assessment (PIPRECIA) methods adapted for group decision-making. In the proposed approach, attitudes of decision-makers are transformed into grey group attitudes, which allows taking advantage of the benefit that grey numbers provide over crisp numbers. The main advantage of the proposed approach in relation to the use of crisp numbers is the ability to conduct different analyses, i.e., considering different scenarios, such as pessimistic, optimistic, and so on. By varying the value of the whitening coefficient, different weights of the criteria can be obtained, and it should be emphasized that this approach gives the same weights as in the case of crisp numbers when the whitening coefficient has a value of 0.5. In addition, in this approach, the grey number was formed based on the median value of collected responses because it better maintains the deviation from the normal distribution of the collected responses. The application of the proposed approach was considered through two numerical illustrations, based on which appropriate conclusions were drawn.

Keywords: grey numbers; group decision-making; PIPRECIA; SWARA

1. Introduction

Multiple-Criteria Decision-Making (MCDM) aims to provide the decision-maker with a choice of the best options from the final set of alternatives by analyzing them from several angles, i.e., through several criteria/attributes. Criteria weights can have a significant impact on the ranking of alternatives or the selection of the most acceptable alternative

in Multiple-Criteria Decision-Making (MCDM). Therefore, many methods have been proposed so far for determining criteria weights—Entropy method [1], Analytic Hierarchy Process (AHP) introduced by Saaty [2], CRiteria Importance Through Intercriteria Correlation (CRITIC) proposed by Diakoulaki et al. [3], Analytic Network Process (ANP) proposed by Saaty and Vargas [4], Step-wise Weight Assessment Ratio Analysis (SWARA) proposed by Kersulienė et al. [5], Best-Worst Method (BWM) proposed by Rezaei [6], Full COnsistency Method (FUCOM) proposed by Pamucar et al. [7], etc.

Besides these methods, there is also a new generation of prominent methods, such as the Characteristic Objects Method (COMET) and its extensions [8–12], the preference ranking organization method for enrichment evaluation (PROMETHEE)—partial ranking and PROMETHEE II—complete ranking [13,14]. The success of these methods is attributed to their correct mathematical settings and ease of application in practice.

Besides determining criteria weights, the SWARA method was used to solve many decision-making problems, as well as to determine the weights of criteria in these problems. Although it can be observed as a relatively new MCDM method, the SWARA method has so far been used for—prioritizing sustainability assessment indicators [15], product design from international and local perspectives [16], evaluation of exterior wall insulation [17], evaluation of packaging design [18], technology foresight about R&D project evaluation [19], regional landslide hazard assessment [20], personnel selection [21], copper prospecting mapping [22], risk assessment [23], engine operating parameter optimization [24], evaluation of smart card systems in public transportation [25], marine energy plant location selection problem [26], evaluation of sustainability indicators for renewable energy [27], evaluation of a house plan shape [28], selection of landfill site [29], supplier selection [30,31], and so forth.

Also, many extensions have been proposed for the SWARA method that extends its application to use with grey [32,33], fuzzy [34], and rough sets [35].

Before applying the SWARA method, it is necessary to rank the criteria according to their expected significance, which in some cases may be a limitation for its use. Therefore, Stanujkic et al. [36] extended the SWARA method intending to enable determining criteria weights even in cases when the criteria are not ranked according to the expected significance, and they proposed the name Pivot Pairwise Relative Criteria Importance Assessment (PIPRECIA) method for the mentioned extension.

Unlike the SWARA method, the PIPRECIA method has been used for solving a significantly fewer number of decision-making problems. The following articles can be mentioned as some examples of the use of this method—determining the significance of criteria for the implementation of high-performance computing in Danube region countries [37], green supplier selection [38], assessing the quality of e-learning materials [39,40], safety evaluation of railway traffic [41], assessment of road transportation risks [42], stackers selection [43], evaluation of the ICT adoption [44], and so forth. Besides, the PIPRECIA method has also been extended for using grey [45] and fuzzy [46] numbers.

Many extensions of MCDM methods that enable using of grey, fuzzy and neutrosophic sets have been done to enable solving complex decision-making problems often associated with the inaccuracy and unreliability of the information used to make decisions. However, many decision-making problems often require the participation, or examination of the attitudes, of more than one decision-maker or respondent. Therefore, in this article, a new grey extension of SWARA and PIPRECIA methods adapted for group decision-making is proposed. In this extension, the attitudes of the respondents collected using crisp values are further transformed into grey interval numbers, thus retaining the possibilities of different analyses.

The main contribution is that the proposed approach allows the attitudes of a larger number of respondents, expressed in crisp numbers, to be transformed into gray intervals based on the median value of the collected responses. The proposed approach can be used as a substitute for approaches in which group decision matrices are formed based on the mean value of the answers received from all respondents. Therefore, the main advantage

of the proposed approach in relation to the use of crisp numbers is the ability to conduct different analyses, i.e., considering different scenarios, such as pessimistic, optimistic, and so on.

Therefore, the remaining part of this article is organized as follows—in Section 2, research methodology is presented with some basic elements of grey set theory and the calculation procedures of the SWARA and PIPRECIA methods are presented. In Section 3, a new approach for transforming respondents’ ratings into appropriate grey interval numbers is presented, while Section 4 presents two numerical illustrations in which the proposed approach is applied. Finally, conclusions are given.

2. Research Methodology

2.1. Grey Numbers

The Grey Systems Theory is an effective methodology that can be used for solving uncertain problems with partially known information [47]. The basic concept of this theory is that all information is classified into three categories, depending on their uncertainty, and the appropriate colors are assigned to them as follows—known information is labeled as white, unknown information is labeled as black, and the uncertainty information is labeled grey. The white, black and grey numbers are shown on Figure 1.

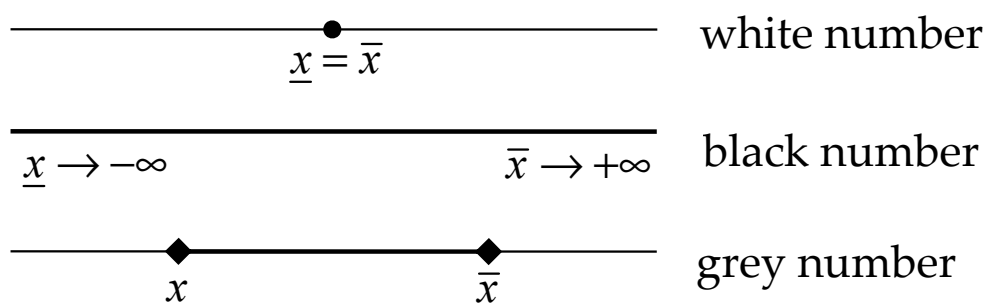


Figure 1. White, black and interval grey numbers.

Definition 1. Grey number [47]. A grey number $\otimes x$ is such a number whose exact value is unknown, but the range in which value can lie is known.

Definition 2. Interval grey number [47]. Interval grey number is a grey number with known lower bound \underline{x} and upper bound \bar{x} , but with unknown value of x , and it is shown as follows:

$$\otimes x \in [\underline{x}, \bar{x}] = [\underline{x} \leq x \leq \bar{x}] \tag{1}$$

Definition 3. Basic operations of grey numbers [34]. Let $\otimes x_1 = [\underline{x}_1, \bar{x}_1]$ and $\otimes x_2 = [\underline{x}_2, \bar{x}_2]$ be two grey numbers. The basic operations of grey numbers $\otimes x_1$ and $\otimes x_2$ are defined as follows:

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

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

$$\otimes x_1 \cdot \otimes x_2 = [\underline{x}_1 \cdot \underline{x}_2, \bar{x}_1 \cdot \bar{x}_2], \tag{4}$$

$$\otimes x_1 \div \otimes x_2 = [\underline{x}_1, \bar{x}_1] \cdot \left[\frac{1}{\underline{x}_2}, \frac{1}{\bar{x}_2} \right]. \tag{5}$$

Definition 4. The whitening function [48]. The whitening function transforms an interval grey number into a crisp number whose possible values lie between the bounds of the interval grey number. For the given interval grey number, the whitened value $x_{(\lambda)}$ of interval grey number $\otimes x$ is defined as

$$x_{(\lambda)} = (1 - \lambda)\underline{x} + \lambda\bar{x}, \quad (6)$$

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:

$$x_{(0.5)} = 0.5(\underline{x} + \bar{x}) \quad (7)$$

2.2. The SWARA and the PIPRECIA Methods

The basic steps of the computational procedures of the SWARA and PIPRECIA methods for determining criteria weights based on the attitudes of a respondent, i.e., decision-maker or expert, are presented in this section.

2.2.1. The SWARA Method

The procedure for determining weights of n criteria by applying the SWARA method can be summarized as follows [5,18]:

Step 1. Identification and selection of criteria;

Step 2. Sorting criteria according to their expected significance, in descending order; and

Step 3. Determining the relative significance of criteria. In this step, the relative significance of the first criterion is set to 1, while the relative significance of the others s_j is determined according to the previous one.

In the SWARA method, s_{j-1} has a value 0 if criterion $j - 1$ has the same significance as the criterion j , $s_j \in [0, 1]$, and the lower value of s_{j-1} indicates a higher significance of criterion j in relation to criterion $j - 1$.

Step 4. Calculating the value of the coefficient k_j as:

$$k_j = \begin{cases} 1 & \text{if } j = 1 \\ s_j + 1 & \text{if } j > 1 \end{cases} \quad (8)$$

Step 5. Calculating the value of the recalculated significance q_j as follows:

$$q_j = \begin{cases} 1 & \text{if } j = 1 \\ \frac{q_{j-1}}{k_j} & \text{if } j > 1 \end{cases} \quad (9)$$

Step 6. Calculating the criteria weights w_j as follows:

$$w_j = \frac{q_j}{\sum_{k=1}^n q_k} \quad (10)$$

The calculation procedure of the SWARA method, for determining the criteria weights, is summarized in Figure 2.

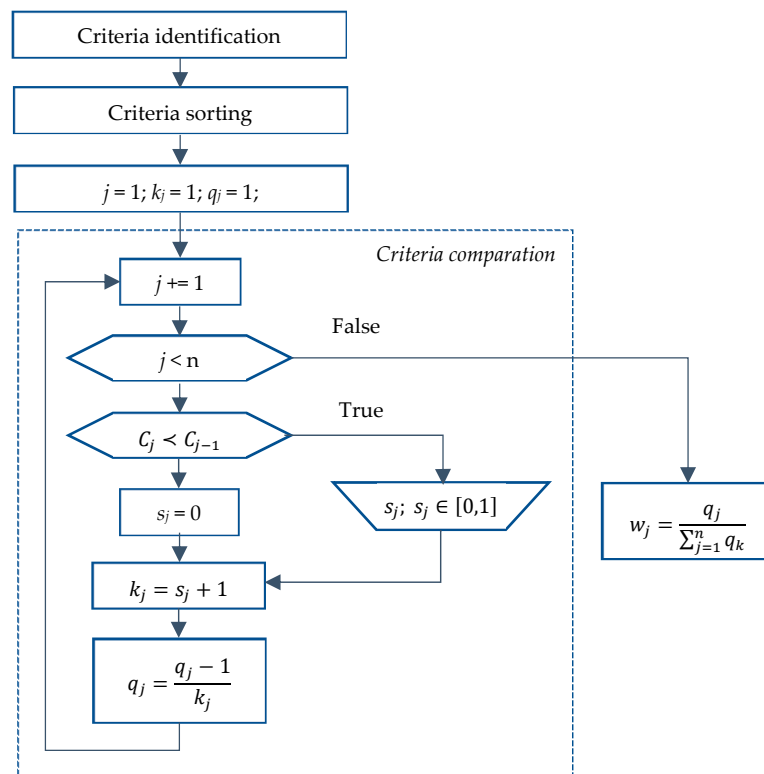


Figure 2. Flowchart of the SWARA method.

2.2.2. The PIPRECIA Method

The procedure for determining criteria weights by applying the PIPRECIA method can be summarized as follows [36]:

Step 1. Identification and selection of criteria;

Step 2. Sorting criteria according to their expected significance, in descending order.

This step is not strictly required in the PIPRECIA method. Unlike the SWARA method, the PIPRECIA method can be used even when it is not possible to assess the significance of the criteria in advance; and

Step 3. Determining the relative significance of criteria. In this step, the relative significance of the first criterion is set to 1, while the relative significance of the others s_j is determined concerning the previous one.

Unlike the SWARA method, in the PIPRECIA method, $s_{j-1} = 1$ if criterion $j - 1$ has the same significance as the criterion j , $s_j \in (1, 2]$ if criterion $j - 1$ has higher significance than criterion j , and $s_j \in (1, 0]$ if criterion $j - 1$ has a lower significance than criterion j .

Step 4. Calculating the value of the coefficient as follows:

$$k_j = \begin{cases} 1 & \text{if } j = 1 \\ 2 - s_j & \text{if } j > 1 \end{cases} \tag{11}$$

Step 5. Calculating the value of the recalculated significance as:

$$q_j = \begin{cases} 1 & \text{if } j = 1 \\ \frac{q_{j-1}}{k_j} & \text{if } j > 1 \end{cases} \tag{12}$$

Step 6. Calculating the criteria weights as:

$$w_j = \frac{q_j}{\sum_{k=1}^n q_k} \tag{13}$$

The calculation procedure of the PIPRECIA method is shown in Figure 3.

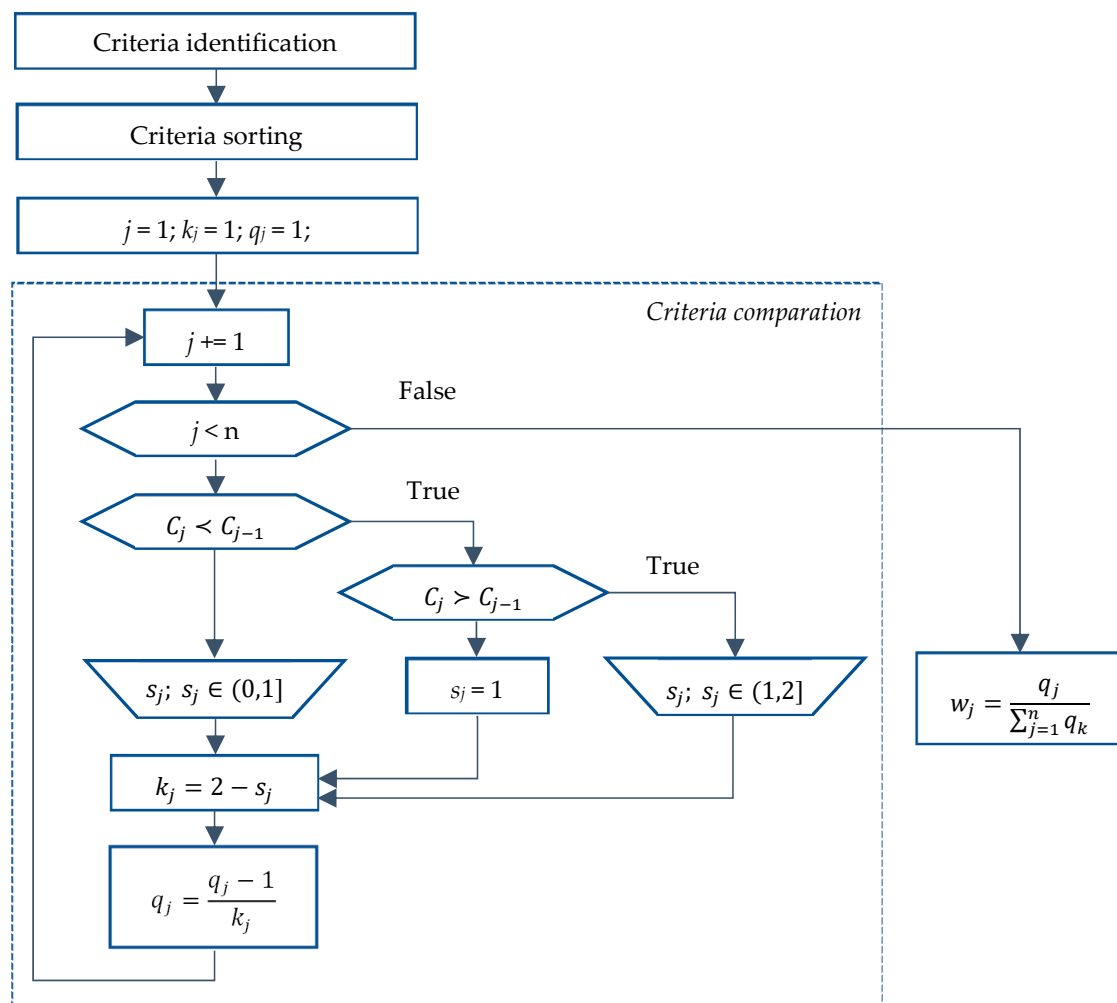


Figure 3. Flowchart of the PIPRECIA method.

From the previously described procedures, it can be concluded that the basic difference between SWARA and PIPRECIA methods is in the way of assigning the relative importance of the criteria, which is manifested in Equation (11) of the calculation procedure of the PIPRECIA method.

In the case of applying the SWARA method, s_j shows how much less important a criterion is than the previous one, which is why it is necessary to pre-rank the criteria according to their expected significance. In contrast, the PIPRECIA method allows the relative significance of the criteria to be less than, equal to, or greater than the significance of the previous criterion, which is why in the case of applying this method it is not necessary to rank the criteria according to their expected significance.

The use of the SWARA method has already been proven in numerous published papers. In contrast, the PIPRECIA method is proposed as an extension of the SWARA method that can be used when it is not possible to determine in advance the expected significance of the criteria, as in the case of surveying the attitudes of a large number of respondents using electronic questionnaires.

There are several ways to apply the previously described single-user procedures SWARA and PIPRECIA methods in the case of solving group decision-making problems. Nevertheless, a new approach for transform individual crisp attitudes into a grey group attitude is proposed and discussed below.

3. A New Grey Approach for Using SWARA and PIPRECIA Methods in a Group Decision-Making Environment

As mentioned above, decision-makers or experts involved in group decision-making assess the values of the relative significance of criteria and express these values using crisp numbers. As a result of group evaluation, K lists of relative significances are formed, where K denotes the number of decision-makers or experts.

In such cases, in order to determine the criteria weights, it is possible to:

- Calculate the group significance as follows:

$$s_j = \frac{1}{k} \sum_{k=1}^K s_j^k, \quad (14)$$

and then apply the SWARA or PIPRECIA method.

- Calculate the criteria weights for each respondent w_j^k , and then calculate the group criteria weight as follows:

$$w_j = \frac{1}{k} \sum_{k=1}^K w_j^k \quad (15)$$

However, in order to take advantage of the benefits that grey numbers provide, i.e., the possibility of analysis, a transformation of respondents' attitudes into grey relative group significance is proposed, using the following steps:

Step 1. Determine the median value mdn_j for each criterion, as follows:

$$mdn_j = \text{median}(s_j^k) \quad (16)$$

Step 2. Determine the lower s_j and upper \bar{s}_j bounds of grey relative group significance for each criterion, as follows:

$$s_j = \text{mean}(s_j^k | s_j^k \leq mdn_j) \quad (17)$$

$$\bar{s}_j = \text{mean}(s_j^k | s_j^k \geq mdn_j) \quad (18)$$

Step 3. Using Equation (6) and different values for the coefficient λ , the relative group significance can be determined after which the criteria weights can be determined using the SWARA or PIPRECIA methods.

Using the proposed approach, the attitudes of a larger number of respondents, i.e., a larger number of crisp ratings, can be transformed into a grey interval, i.e., only two crisp numbers, without significant loss of information.

This means that the proposed approach can provide similar results to approaches in which crisp numbers are used, but it also provides an additional possibility to conduct analyses. The word similar is used here because in this approach the edges of the interval are formed based on the median values of the scores collected from all the respondents. Identical weights of the criteria, when the whitened value is 0.5, could be achieved if the limits of the grey number were formed on the basis of the mean value instead of the median value of the collected relative significances. However, in this approach, forming of the grey number based on the median value of collected relative significances was selected because it better maintains the deviation from the normal distribution in the collected relative significances.

4. A Numerical Illustrations

To present the proposed approach in detail, as well as its verification, this section presents the results of two studies conducted by a group of 10 master and doctoral students from the Faculty of Applied Management, Economics and Finance (MEF), Belgrade, Serbia. Before beginning research about evaluation criteria for assessing the quality of websites, students involved in the research are thoroughly introduced using the SWARA and PIPRECIA methods.

4.1. The First Numerical Illustration

To verify and explain in more detail the proposed approach, a study with doctoral and master students, familiar with the use of SWARA and PIPRECIA methods, was conducted. On that occasion, the significance of five criteria for evaluating travel and tourism website design ideas, such as On the Grid (<https://onthegrid.city/> (accessed on 1 March 2021) [49]), Visit Asia (<https://www.visitasiatravel.com/> (accessed on 1 March 2021) [50]), Visit Australia (<https://www.australia.com/en> (accessed on 1 March 2021) [51]), Live Africa (<http://www.liveafrica.com/> (accessed on 1 March 2021) [52]), Bora Bora (<https://www.borabora.com/> (accessed on 1 March 2021) [53]), Visit Serbia (<https://www.serbia.travel/en> (accessed on 1 March 2021) [54]) and National Park Djerdap (<https://npdjerdap.rs/en/> (accessed on 1 March 2021) [55]), was determined.

Based on 7 criteria proposed by the 2020 WebAward Competition (<http://www.webaward.org/> (accessed on 1 March 2021) [56]), that are, Design, Innovation, Content, Technology, Interactivity, Copywriting, and Ease of use, the following five criteria are defined for evaluating travel and tourism website design ideas:

- Cr_1 , Availability of information;
- Cr_2 , Structure and navigability;
- Cr_3 , Design;
- Cr_4 , Personalization; and
- Cr_5 , Innovations.

On that occasion, in interactions with the respondents, their meaning was precisely determined. During this evaluation, we gave the following meaning to the criteria—Criterion Cr_1 refers to the availability of useful information about the tourist destination on the website, while criterion Cr_2 , Structure and navigability, refers to the organization of information in such a way that visitors to the website can easily find it. The criterion Cr_3 , Design, refers to the visual appearance of the website and its success to convey the beauty of tourist destinations. The Cr_4 criterion indicates the ability to tailor the website to the needs of visitors. This criterion includes the ability to choose the language in which the information is displayed, the use of search bars, as well as responsive web design. Finally, the criterion Cr_5 , Innovations, refers to the application of current technologies and innovations in web design.

After choosing the criteria, and considering their significances and impact, during a tour of the above-mentioned websites, respondents gave their attitudes, which are shown in Table 1. It should be noted that the above criteria are listed in order of their expected significance, which is necessary for the application of the SWARA method.

Table 1. Attitudes of respondents as results of the SWARA method.

	E_1	E_2	E_3	E_4	E_5	E_6	E_7	E_8	E_9	E_{10}	Mean
Cr_1	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Cr_2	0.00	0.05	0.06	0.20	0.15	0.01	0.03	0.18	0.15	0.20	0.10
Cr_3	0.15	0.10	0.10	0.20	0.20	0.05	0.10	0.20	0.15	0.20	0.15
Cr_4	0.25	0.15	0.10	0.25	0.30	0.10	0.15	0.23	0.17	0.25	0.20
Cr_5	0.25	0.20	0.20	0.30	0.40	0.15	0.15	0.25	0.20	0.30	0.24

Table 1 also shows the mean value of the attitudes of all respondents for each criterion. The calculation details and criteria weights obtained based on the mean value, calculated by applying the SWARA method, are encountered in Table 2.

Table 2. Computational details and criteria weights generated by the SWARA method based on mean values.

	Mean	k_j	q_j	w_j'	Rank
Cr_1	1.00	1	1	0.257	1
Cr_2	0.10	1.10	0.91	0.233	2
Cr_3	0.15	1.15	0.79	0.203	3
Cr_4	0.20	1.20	0.66	0.170	4
Cr_5	0.24	1.24	0.53	0.137	5

The individual criteria weights calculated on the attitudes of each respondent are shown in Table 3. Table 3 also shows group criteria weights calculated as the average of individual criteria weights.

Table 3. Individual and group criteria weights calculated by the SWARA method.

	w_{e1}	w_{e2}	w_{e3}	w_{e4}	w_{e5}	w_{e6}	w_{e7}	w_{e8}	w_{e9}	w_{e10}	w_j''
Cr_1	0.24	0.24	0.24	0.28	0.28	0.22	0.23	0.28	0.26	0.28	0.256
Cr_2	0.24	0.23	0.22	0.24	0.24	0.22	0.23	0.24	0.23	0.24	0.232
Cr_3	0.21	0.21	0.20	0.20	0.20	0.21	0.21	0.20	0.20	0.20	0.203
Cr_4	0.17	0.18	0.18	0.16	0.16	0.19	0.18	0.16	0.17	0.16	0.170
Cr_5	0.14	0.15	0.15	0.12	0.11	0.16	0.16	0.13	0.14	0.12	0.138

From Tables 2 and 3, it can be seen that both approaches give the same criteria weights, as well as the same ranking order of criteria based on their significance, that is $Cr_1 \succ Cr_2 \succ Cr_3 \succ Cr_4 \succ Cr_5$, which confirms that the expected significance of the criteria was correctly assessed, as well as that all respondents filled in the questionnaires correctly.

It is important to note here that the evaluation was performed by respondents familiar with the methods used and that they entered their views in a questionnaire made in the spreadsheet program which immediately calculated criteria weights and displayed values numerically and graphically after entering the relative significance of each criterion. In this way, the respondents were able to correct their grades if necessary. Respondents were also suggested that they could modify their responses until they gained criteria weights that reflected their real opinion.

Determining the Criteria Weights Based on the Proposed Grey Approach

Determining criteria weights using the proposed approach began by determining the median values for each criterion, after which the lower and upper bounds of the grey numbers were determined. The median, lower and upper bounds of grey numbers are arranged in Table 4. Table 4 also shows the values of relative group significance obtained by applying Equation (6) and $\lambda = 0.5$, as well as its deviations from the mean.

Table 4. Median, left, and right bounds of grey ratings.

	mdn_j	s_{-j}	\bar{s}_j	$s_j^{0.5}$	Δ	$\Delta\%$
Cr_1	0.24	0.24	0.24	0.28	0.28	0.22
Cr_2	0.24	0.23	0.22	0.24	0.24	0.22
Cr_3	0.21	0.21	0.20	0.20	0.20	0.21
Cr_4	0.17	0.18	0.18	0.16	0.16	0.19
Cr_5	0.14	0.15	0.15	0.12	0.11	0.16

Due to the complexity of the procedure for determining the left and right bounds of the grey interval, the calculation was performed using a program written in the Python programming language.

The criteria weights determined based on the left and right boundaries of the grey interval are shown in Table 5. The criteria weights calculated using Equation (6) and $\lambda = 0.5$ are also shown in Table 5.

Table 5. The criteria weight obtained based on grey ratings.

	w_{-j}	\bar{w}_j	w_j'''
Cr_1	0.279	0.234	0.257
Cr_2	0.237	0.227	0.233
Cr_3	0.201	0.205	0.203
Cr_4	0.160	0.181	0.170
Cr_5	0.123	0.153	0.137

Table 6 shows the criteria weights obtained based on the mean value of relative significance (w_j'), the mean values of the weights obtained based on the respondents' attitudes (w_j''), and the weights obtained by applying the proposed approach (w_j''').

Table 6. The criteria weight obtained using three approaches.

	w_j'	w_j''	w_j'''
Cr_1	0.257	0.256	0.257
Cr_2	0.233	0.232	0.233
Cr_3	0.203	0.203	0.203
Cr_4	0.170	0.170	0.170
Cr_5	0.137	0.138	0.137

It can be noticed from Table 6 that all three considered approaches give almost the same criteria weights.

To verify the applicability of the proposed approach in the case of application of the PIPRECIA method, the values in Table 1 were recalculated as follows:

$$s_j = \begin{cases} 1 & \text{if } j = 1 \\ 1 - s_j & \text{if } j > 1 \end{cases} \tag{19}$$

This recalculation was necessary due to differences in the calculation of the coefficient k_j , i.e., in Equations (8) and (11), in the SWARA and PIPRECIA methods. This way of value transformation was chosen because the aim of this research was not to compare the results obtained using the SWARA and PIPRECIA methods but to check the applicability of the proposed procedure. The results achieved using SWARA and PIPRECIA could differ to some extent because the relatively important feature is the assessment of the respondent. Even in the case of re-evaluation using some of the above methods, certain deviations may occur.

The recalculated values from Table 1 are shown in Table 7.

Table 7. Attitudes of respondents adapted for applying the PIPRECIA method.

	E_1	E_2	E_3	E_4	E_5	E_6	E_7	E_8	E_9	E_{10}	Mean
Cr_1	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Cr_2	1.00	0.95	0.94	0.80	0.85	0.99	0.97	0.82	0.85	0.80	0.90
Cr_3	0.85	0.90	0.90	0.80	0.80	0.95	0.90	0.80	0.85	0.80	0.86
Cr_4	0.75	0.85	0.90	0.75	0.70	0.90	0.85	0.77	0.83	0.75	0.81
Cr_5	0.75	0.80	0.80	0.70	0.60	0.85	0.85	0.75	0.80	0.70	0.76

The values obtained using the three approaches, and the PIPRECIA method, are given in Tables 8–10, while the comparison of weights obtained using the three approaches is summarized in Table 11.

Table 8. Computational details and the criteria weights obtained by the PIPRECIA method based on mean values.

	Mean	k_j	q_j	w_j'
Cr_1	1.00	1	1	0.257
Cr_2	0.90	1.10	0.91	0.233
Cr_3	0.86	1.15	0.79	0.203
Cr_4	0.81	1.20	0.66	0.170
Cr_5	0.76	1.24	0.53	0.137

Table 9. Individual and group criteria weights calculated using the PIPRECIA method.

	e_1	w_{e2}	w_{e3}	w_{e4}	w_{e5}	w_{e6}	w_{e7}	w_{e8}	w_{e9}	w_{e10}	w_j''
Cr_1	0.24	0.24	0.24	0.28	0.28	0.22	0.23	0.28	0.26	0.28	0.256
Cr_2	0.24	0.23	0.22	0.24	0.24	0.22	0.23	0.24	0.23	0.24	0.232
Cr_3	0.21	0.21	0.20	0.20	0.20	0.21	0.21	0.20	0.20	0.20	0.203
Cr_4	0.17	0.18	0.18	0.16	0.16	0.19	0.18	0.16	0.17	0.16	0.170
Cr_5	0.14	0.15	0.15	0.12	0.11	0.16	0.16	0.13	0.14	0.12	0.138

Table 10. The criteria weight obtained based on grey ratings.

	mdn_j	s_{-j}	\bar{s}_j	$s_j^{0.5}$	w_j'''
Cr_1	1.000	1.000	1.000	1.000	0.257
Cr_2	0.895	0.824	0.970	0.897	0.233
Cr_3	0.850	0.817	0.892	0.854	0.203
Cr_4	0.800	0.744	0.866	0.805	0.170
Cr_5	0.775	0.700	0.820	0.760	0.137

Table 11. The criteria weight obtained using three approaches.

	w_j'	w_j''	w_j'''
Cr_1	0.257	0.256	0.257
Cr_2	0.233	0.232	0.233
Cr_3	0.203	0.203	0.203
Cr_4	0.170	0.170	0.170
Cr_5	0.137	0.138	0.137

As in the case of using the SWARA method, it can be seen from Table 11 that all three approaches give almost the same criteria weights.

Finally, Table 12 shows a comparison of criteria weights obtained using the SWARA and PIPRECIA methods, the proposed grey approach, and $\lambda = 0.5$.

Table 12. The comparison of criteria weight obtained using the SWARA and PIPRECIA methods.

	SWARA	PIPRECIA
	w_j'''	w_j'''
Cr_1	0.257	0.257
Cr_2	0.233	0.233
Cr_3	0.203	0.203
Cr_4	0.170	0.170
Cr_5	0.137	0.137

As can be seen from Table 12, both approaches give the same criteria weights.

4.2. The Second Numerical Illustration

In the second part of the research, the aforementioned group of students determined the significance of the criteria for evaluating e-commerce websites, from the viewpoint of first-time visitors, using the PIPRECIA method. On this occasion, the significance of the following criteria, adopted from Stanujkic and Magdalinovic [57], was determined:

- Cr_1 , Design of the website;
- Cr_2 , Easy to use;
- Cr_3 , Quality and availability of information;
- Cr_4 , Ordering process; and
- Cr_5 , Security assurance.

In this evaluation, the following meanings were assigned to the above-mentioned criteria. Criterion Cr_1 refers to the website’s design, while criterion Cr_2 , Easy to use, refers to the possibility of easily finding the desired product and the possibility of sorting and selecting products. Criterion Cr_3 refers to the information about products and organization of information to enable easier decision-making about ordering products. Criterion Cr_4 refers to the complexity, intuitiveness, and flexibility of the ordering process, while criterion Cr_5 , Security assurance, refers to the assessment of ordering security from the website in the sense that they will actually receive products of appropriate quality, and the possibility of complaints and the security of their personal information and payment card numbers.

After discussing the meaning of the above criteria, a list that contained five e-commerce websites, that none of the respondents had visited before, was formed. This list of websites was compiled by the following websites—www.eponuda.com (accessed on 21 March 2021) [58], www.gamecentar.rs (accessed on 21 March 2021) [59], www.mi-srbija.rs (accessed on 21 March 2021) [60], www.3gstore.rs (accessed on 21 March 2021) [61], and www.lalafo.rs (accessed on 21 March 2021) [62].

The attitudes of the respondents collected during the evaluation are shown in Table 13, as well as their mean.

Table 13. Respondents’ attitudes obtained based on the use of the PIPRECIA method.

	E_1	E_2	E_3	E_4	E_5	E_6	E_7	E_8	E_9	E_{10}	Mean
Cr_1	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Cr_2	1.20	1.10	1.00	1.00	1.05	0.80	0.90	1.20	1.10	1.15	1.05
Cr_3	1.20	1.00	1.00	1.20	1.10	1.20	1.20	1.20	1.20	1.30	1.16
Cr_4	1.00	1.10	0.90	1.00	1.00	0.90	1.10	1.10	1.00	1.00	1.01
Cr_5	1.10	1.10	1.10	1.00	1.00	1.05	0.90	1.00	1.00	1.00	1.03

The calculation details and the criteria weights obtained based on the mean value are encountered in Table 14, while the group criteria weights, calculated based on the average of individual criteria weights, are shown in Table 15.

Table 14. The computational details and the criteria weights obtained using the PIPRECIA method based on mean values.

	Mean	k_j	q_j	w_j'
Cr_1	1.00	1	1	0.170
Cr_2	1.05	0.95	1.05	0.179
Cr_3	1.16	0.84	1.25	0.213
Cr_4	1.01	0.99	1.27	0.216
Cr_5	1.03	0.98	1.30	0.221

Table 15. Individual and group criteria weights calculated by applying the PIPRECIA method.

	w_{e1}	w_{e2}	w_{e3}	w_{e4}	w_{e5}	w_{e6}	w_{e7}	w_{e8}	w_{e9}	w_{e10}	w_j''
Cr_1	0.14	0.17	0.20	0.17	0.18	0.21	0.18	0.14	0.16	0.14	0.170
Cr_2	0.18	0.19	0.20	0.17	0.19	0.17	0.17	0.17	0.18	0.16	0.179
Cr_3	0.22	0.19	0.20	0.22	0.21	0.22	0.21	0.21	0.22	0.23	0.213
Cr_4	0.22	0.21	0.18	0.22	0.21	0.20	0.23	0.24	0.22	0.23	0.216
Cr_5	0.24	0.24	0.21	0.22	0.21	0.21	0.21	0.24	0.22	0.23	0.221

The criteria weights obtained using the proposed approach are shown in Table 16. Finally, the comparisons of weights obtained using three approaches are presented in Table 17.

Table 16. The criteria weight obtained based on grey ratings.

	mdn_j	s_{-j}	\bar{s}_j	$s_j^{0.5}$	w_j'''
Cr_1	1.000	1.000	1.000	1.000	0.169
Cr_2	0.895	0.824	0.970	0.897	0.178
Cr_3	0.850	0.817	0.892	0.854	0.216
Cr_4	0.800	0.744	0.866	0.805	0.217
Cr_5	0.775	0.700	0.820	0.760	0.220

Table 17. The criteria weight obtained using three approaches.

	w_j'	w_j''	w_j'''
Cr_1	0.170	0.170	0.169
Cr_2	0.179	0.179	0.178
Cr_3	0.213	0.213	0.216
Cr_4	0.216	0.216	0.217
Cr_5	0.221	0.221	0.220

As can be observed from Table 17, all considered approaches gave almost the same criteria weights.

5. Conclusions

An innovative approach for determining criteria weights in case of group decision-making, using SWARA or PIPRECIA methods, is proposed in this article.

In this approach, it is proposed to transform the respondents' attitudes into appropriate grey intervals, instead of transforming them into crisp values. Using grey, instead of crisp, numbers provides much greater possibilities, primarily for performing certain analyses. Therefore, in this article, two numerical examples were conducted and the justification of the proposed approach is confirmed. Also, by varying the value of the whitening coefficient, different weights of the criteria can be obtained, and it should be emphasized that this approach gives the same weights as in the case of crisp numbers when the whitening coefficient has a value of 0.5.

The study was conducted with a group of 10 selected respondents from a group of 25 respondents who were instructed to apply the SWARA and PIPRECIA methods.

The results obtained by applying the proposed approach, in the considered cases, are identical to the results obtained by the used procedures based on the application of crisp numbers. Besides, the results obtained using the SWARA and PIPRECIA methods are the same in all cases considered, which confirms that this approach can be used with the SWARA and PIPRECIA methods.

The advantage of this approach is reflected in the possibility of combining crisp and grey numbers, where crisp numbers are used for collecting the respondents' attitudes, while grey numbers are used for expressing attitudes of all respondents that are group

attitudes. In this way, the possibility of a simple collection of respondents' attitudes and the advantages of grey numbers is combined, primarily in terms of conducting analyses.

In addition, in this approach, the grey number was formed based on the median value of collected responses because it better maintains the deviation from the normal distribution of the collected responses.

The proposed approach can be used for determining the criteria weights as well as for completely solving the MCDM problem. Finally, as a direction for future research, the proposed approach can be easily adapted for applying triangular fuzzy numbers, or even interval-valued triangular fuzzy numbers, i.e., new extensions for solving a wider spectrum of complex real-world problems could be proposed.

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