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Selection of a Green Contractor for the Implementation of a Solar Power Plant Project

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Abstract: This study is focused on the problem of contractor selection for the implementation of a solar power plant project to produce electricity from sustainable sources for the needs of the company Voćar. The goal of this research is to select a construction contractor to install a solar power plant using sustainability criteria. With this power plant, the company Voćar can reduce its electricity costs and contribute to the production of sustainable energy. A total of three main sustainability criteria were used, in which six auxiliary criteria were symmetrically distributed. With these criteria, six suppliers were analyzed, and expert decision making was carried out with the application of the fuzzy–rough approach. To define the weights of the criteria, the SWARA method was utilized in this study. Based on the findings of this method, the most important criteria are the ecological criteria. Using the CRADIS method, the contractors were ranked, and the results show that contractor C6 has the best results and is the first choice for implementing this project. Choosing the best supplier increases the sustainability of project implementation and the realization of the expected effects.

Keywords: project implementation; selection of contractors; sustainability; fuzzy–rough approach; group expert decision making; solar power plant

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1. Introduction

The purpose of project management is to plan and implement specific projects [1]. Project implementation is the central phase of every project, and at the same time, the phase in which planned activities are executed [2]. During the implementation, the project may include construction work. Not all companies have the capacity for construction work, and they are required to hire construction contractors to complete this work [3]. During the selection of construction companies, the selection of potential criteria is first carried out, and the contractors who will assist in the execution according to the selected criteria are selected [4]. This process differs from the classic supplier selection process, because instead of delivering goods or materials, here, construction work is performed.

Nowadays, due to the growing concern for the ecosystem and people, food companies place their emphasis on environmental protection and energy production from sustainable sources, including solar energy. To implement these projects, food companies emphasize the selection of green construction contractors [5] due to the specificity of these projects. Based on this, sustainability has become imperative when selecting a construction contractor to install solar power plants [6]. In this way, the balanced need satisfaction of current generations is ensured without jeopardizing the needs of future generations. The selection of an environmentally friendly contractor for those projects plays a pivotal role for the sustainability of the project. Traditional approaches for the selection of a construction contractor often rely on purely economic criteria [7], which aim to carry out construction work more efficiently and effectively while reducing costs. The inclusion of environmental and social criteria when selecting construction companies requires the application of more sophisticated decision-making models [8].

Agri-food companies strive to minimize the adverse impacts on the environment to improve their reputation in the eyes of customers and interest groups [9]. These companies are increasingly choosing to install solar panels to produce electricity from sustainable sources to use in their production [10]. In this way, they protect the environment, and at the same time, reduce production costs, because electricity is the most important cost in the production of food and beverages [11]. More companies are oriented to this approach, but since they do not have the necessary capacity to realize these projects, they have to hire a contractor.

The use of solar power plants has become popular among companies. The reason for this is multifaceted. First of all, solar power plants produce electricity, which is necessary for the operation of every company. Furthermore, the production of electrical energy is achieved from sustainable sources, contributing to environmental protection. With the increase in the production of electricity using solar panels, the production of energy from other sources, including fossil fuels, is reduced [12]. Furthermore, the electricity produced internally by the company does not need to be paid to external parties, which reduces business costs. Based on this, the company that uses power plants, as well as the local community, benefit from the construction of solar power plants, because there is less of a negative impact on the environment when energy is generated from sustainable sources. This is the rationale behind further studying the area mentioned and selecting a supplier who will support the efforts of companies in achieving this aim. It should be noted that if the geographical location of the company is favorable, the justification of this project increases [13]. In addition, more companies are deciding to install these panels, thus reducing their costs and impact on environmental pollution, because most of the electricity in Bosnia and Herzegovina is produced from non-environmentally friendly sources. In addition to the geographical location, it is also necessary to take into account the technology used in individual solar panels. This is because some panels have a different energy recovery time compared to other panels [14]. Therefore, before choosing a supplier, an adequate type of solar panel should be purchased, which will give a better return on investment through the production of a larger amount of electricity. According to Rajput et al. [14], the technology for making solar panels, HIT PV module technology, has the best return, so these panels should be used as much as possible in practice.

When implementing these projects, it is necessary to include uncertainty in the decision-making process [15]. Furthermore, as it is impossible to have every detail required, the decision-making process cannot be based on the usage of incomplete information, especially about another company [16]. Thus, decision making should be based on the application of fuzzy and rough approaches. This study investigates the application of the fuzzy–rough (initialism: FR) approach in the process of selecting green construction contractors to promote sustainability in the production of food and beverages through the installation of a solar power plant. The FR approach solves the problems of uncertainty and ambiguity in the data used [17], achieving greater robustness during decision making. The combination of fuzzy logic, which deals with vagueness in data, and the rough set theory, which treats uncertainty, provides a powerful tool for analysis and decision making in the context of selecting an eco-friendly contractor. In addition, the rough set theory helps to reduce subjectivity in decision making [18].

The objectives of this study are reflected in the following:

- Understand the application of the FR approach in the context of selecting construction contractors for the realization of a solar power plant, where the key elements of the FR approach are applied in the making of decisions;
- Identify the key sustainability criteria that are relevant for the implementation of solar power plant projects that include the economic, environmental, and social aspects of sustainability;
- Develop an FR model for evaluating construction contractors based on the sustainability criteria, integrating vagueness and uncertainty in decision making;
- Apply the proposed model to a real example of selecting a green construction contractor for the construction of a solar power plant;

- Identify possible directions for future research and improvements in the field of eco-friendly construction contractor selection using the FR approach, especially for environmental projects.

Based on these research objectives, the following research question is raised: Which contractor would best enable the implementation of the electric power plant construction project for the company Voćar to improve its business, and how would this power plant assist in the future operations of this company?

Based on these research objectives, the following contributions will be made:

- The application of the FR approach in the selection of green contractors enables modeling based on vague and incomplete information;
- The selection of eco-friendly contractors during the implementation of the solar power plant project enables the application of sustainable practices in that project;
- Selecting the appropriate contractor by applying sustainability criteria enables better project management through the use of ecological materials and focus on energy efficiency, recycling, and waste reduction;
- Promoting sustainable practices within the project contributes to the more efficient management of these projects;
- Applying this approach reduces risks and uncertainty and increases the robustness of the entire process of selecting a green contractor for the implementation of environmental projects.

To put this into effect, a hybrid FR approach was adopted. This approach was built on the application of two methods: the CRADIS method to rank the selected contractors, and the SWARA method to determine the weights of the criteria. Applying a combination of these two methods enables the selection of green contractors based on the application of expert decision making and the usage of linguistic values to evaluate the importance of the criteria against selected contractors.

This paper is organized as follows: The Introduction is followed by a review of the literature, where the application of MCDM methods in the selection of suppliers in the implementation of construction projects is presented. This is followed by the section Materials and Methods, where the approach and the methods are explained. This section is followed by a Case Study, where the used case study is explained. This is followed by the Results and Discussion, where the explained methods are applied to an example in practice. At the end of this paper is the Conclusions, where the most important results of this research are given, as well as the research limitations and guidelines for future research.

2. Literature Review

The literature on the selection of contractors in the implementation of different projects is quite extensive. This section reviews some of those previous studies.

Chen et al. [19] used the ELECTRE III method in their research to select contractors in a model based on vagueness, imprecision, and uncertainty. El-Sayegh et al. [20] highlighted the selection of construction contractors in the United Arab Emirates (UAE), with an emphasis on green building projects. Yazdani et al. [21], in their work, selected suppliers of construction materials for the realization of construction projects, and they used gray numbers with the DEMATEL approach, BWM, and CoCoSo method.

Naik et al. [22] evaluated the pre-qualification conditions that contractors fulfill for the realization of construction projects, and they used the CRITIC and EDAS methods. Shojaei and Bolvardizadeh [23] selected a green supplier of building materials for the implementation of construction projects at a university, using the AHP and TOPSIS methods with a rough approach. Morkunaite et al. [24] selected contractors for the reconstruction and rehabilitation projects of cultural heritage buildings that have architectural, historical, and cultural value using the PROMETHEE method.

Cheaitou et al. [25] used mixed integer programming in their research to select the best contractor for construction projects, using the DEA method. Birjandi et al. [26], in their paper, drew attention to the importance of the selection of contractors in the implementation of construction projects, in which they emphasized uncertainty when making decisions in the construction of power plants. Noorzai [27] used the AHP method to select contractors for construction projects in an example of highway construction in Iran. Mahamadu et al. [28] selected a designer for construction work using information modeling of buildings.

In their paper, Demetracopoulou et al. [29] emphasized that it is necessary to properly allocate the risk when selecting a contractor in the highway sector. Morkunaite et al. [30] selected contractors for specific construction work for the restoration of the facade systems in cultural heritage buildings using the AHP, SWARA, and WASPAS methods. Marović et al. [31] observed the selection of construction contractors through the procurement process, where the selection of those who provide the most economically advantageous offer is planned, and they made their selection using the AHP and PROMETHEE methods. Štilić et al. [32] observed the procurement process from the perspectives of the contractors, where they analyzed how they can influence an offer to be selected in the public procurement process, and they considered their strategies by applying the principles of game theory and using the MABAC method.

Cao et al. [33], in their study, dealt with the selection of contractors for the installation of solar panels to produce electricity from renewable energy sources, using the SWARA and FUCOM methods to determine the weights of the criteria while ranking the contractors. Using the EDAS method, they applied a gray relational analysis (GRA). Antoniou and Aretoulis [34] selected contractors using the TOPSIS method for two pilot projects in Greece. Afolayan et al. [35] examined the importance of criteria in the selection of construction contractors using the fuzzy AHP method.

In addition to these and similar studies, the selection of green contractors was also carried out in practice. Erdogan et al. [7] used the AHP method to select a contractor for sustainable construction projects in Turkey. AbouHamad and Abu-Hamd [36] developed a framework for the selection of contractors for low-rise and high-rise buildings using energy efficiency and environmentally protective sources with a Monte Carlo simulation. Figueiredo et al. [37] tried to apply sustainability in construction, emphasizing that the selection of the materials used greatly affects the sustainability of the building, and they tried to identify the key factors that influence it. Gurgun and Koc [38] selected contractors for the sustainable construction of green building projects, and using the AHP method, they identified the key criteria that influenced that choice. In their study, Mensah et al. [39] investigated which theories of ecologically sustainable construction according to Agenda 21 should be used to give guidelines on how to choose a contractor for this type of construction.

At the end of this literature review, it is necessary to mention the importance of solar power plants for the food industry. Herrando et al. [40] studied the feasibility of installing PVT collectors to heat water for a company engaged in processing and canning vegetables. They proved that these collectors reduce production costs by reducing the use of fossil fuels. Ortiz-Rodríguez et al. [41] emphasized that the food industry accounts for 30% of global energy consumption, so it is necessary to use sustainable energy sources in this industry. They proposed the use of solar systems for food drying or dehydration to reduce CO_2 emissions.

In his study, Sgroi [42] argued that it is necessary to produce more electrical energy from sustainable sources, where solar power plants have a special place. This form of producing electricity should be used for food production for food businesses to be more competitive. Dekhil [43] worked on improving the heat exchange in food production related to the use of renewable sources. Manyako et al. [44], in their research, considered the possibility of using energy from solar panels to obtain a large amount of saturated steam, which is used in the production of essential oils from fruits. Cattaneo et al. [45] examined the possibility of using a solar power plant in fruit drying processes to increase dehydration. Based on these and similar studies, it can be confirmed that the use of solar power plants contributes to the efficiency of food companies' business operations. That is why the installation of these power plants has become a need for all companies.

Based on these and similar studies, it can be seen that when selecting a contractor, it is crucial to choose the contractor who will assist in realizing the goals of the project, especially if they are about the realization of a sustainable project. The sustainability of the project is to be included in all phases, including the construction phase of the project, while the selection of the contractors is mainly accomplished by applying methods for multi-criteria decision making.

3. Materials and Methods

In this study, SWARA-CRADIS methods are integrated into the FR approach. This approach enables a correlation between symmetry concepts through a balanced process of making decisions based on different selection criteria. This means that before deciding on the weights of the criteria, a balanced approach is applied, in which all sustainability criteria have the same chance to gain more weight in the decision-making process. The application of the FR approach enables the evaluation of all contractors against all relevant sustainability criteria without bias.

This approach has two phases. The first stage includes the calculation of the criterion weights using the FR SWARA method. The second phase includes the ranking of observed suppliers using the FR CRADIS method (Figure 1).

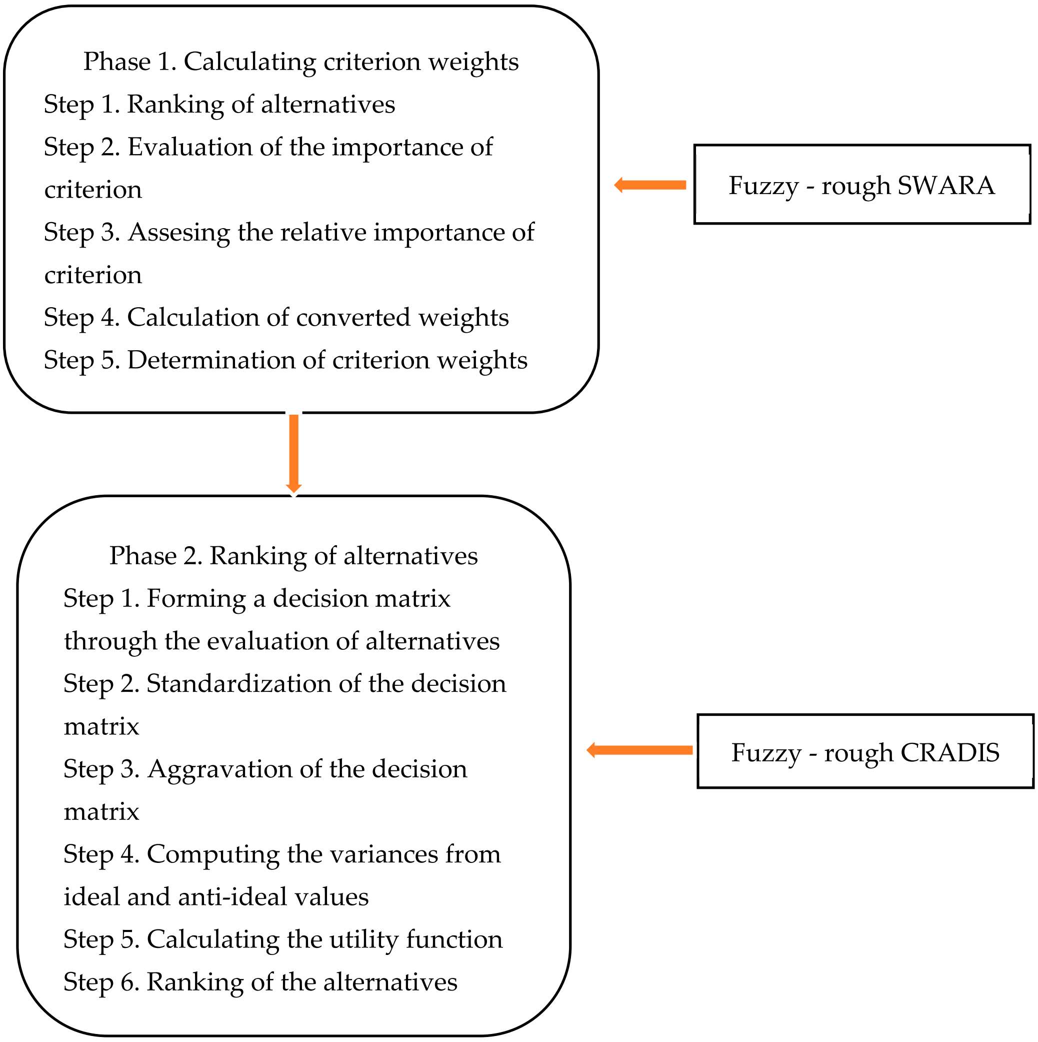

Figure 1. Methodological procedure.

3.1. Fuzzy–Rough Approach

When using the FR approach, the rules for the fuzzy approach, and then those for the rough approach, are used. First, the fuzzy approach was applied. With the fuzzy approach, the evaluations for the criteria and alternatives, which are in the form of linguistic values, were transformed into fuzzy numbers. This was accomplished by applying the defined membership function (Table 1).

Table 1. Value scale and membership functions.

Linguistic Value	Membership Functions	Linguistic Value	Membership Functions
Very poor	(8, 9, 10)	Very poor	(1, 1, 2)
Poor	(6, 7, 8)	Poor	(2, 3, 4)
Mild poor	(5, 6, 7)	Mild poor	(3, 4, 5)
Fair	(4, 5, 6)	Fair	(4, 5, 6)
Mild good	(3, 4, 5)	Mild good	(5, 6, 7)
Good	(2, 3, 4)	Good	(6, 7, 8)
Very good	(1, 1, 2)	Very good	(8, 9, 10)

In this paper, the corrected membership function based on the paper by Pamučar et al. is used [9], as well as that by Puška et al. [17]. The goal of this membership function is to give the lowest priority to the lowest score for the criteria and the highest priority to the highest score for the alternatives. To facilitate the decision making regarding the importance of certain criteria as well as the assessment of certain alternatives, the same value scale was used. However, the function of belonging for the linguistic value to the corresponding fuzzy number was defined differently depending on whether this scale of values was used for the evaluation of criteria or alternatives. In the evaluation of the criteria, the value "very poor" has the highest value in the fuzzy number, while "very good" has the lowest value; in the evaluation of the alternatives, it is the other way around. This enables the determination of the weights of the specific criteria, which makes ranking the alternatives possible.

Since fuzzy numbers are formed, it is necessary to define the lower limits and upper limits of the rough number for each of these fuzzy numbers. This was achieved by looking at the individual evaluations of experts. For the lower limit, each expert's rating that is the same or less than that of the observed expert is considered, and the average rating that represents the lower limit of the rough number is sought [46]. To form the upper limit, the individual evaluations of experts that are the same or higher than that of the observed expert are looked at, and the average evaluation is calculated. In this way, lower and upper limits are formed for each expert. Applying the fuzzy approach enables the application of vague and imprecise information in decision making. The rough approach takes into consideration the uncertainty in making business decisions, and with the assistance of these rough number limits, the subjectivity of the experts is reduced [47].

For this approach, it is necessary to define what FR numbers are and how to perform operations with these numbers. Here, we assume that U (universe) are fuzzy values $(\widetilde{X}_i)$ marked as $\widetilde{X}_i = \left(x_i^l, x_i^m, x_i^u\right)(i = 1, 2, \ldots, n)$. If we assume that $\theta^e = \left\{x_1^e, x_2^e, \ldots, x_n^e\right\}$ $(e = l, m, n)$, then the lower and upper limits of the element $\widetilde{X}_i$, which represent the rough numbers, can be defined as follows [48]:

$$\underline{Lim}(c_i^e) = \frac{1}{\underline{N^e}} \sum_{i=1}^{N^e} \varphi \epsilon \underline{Apr}(c_i^e), \tag{1}$$

$$\overline{Lim}(c_i^e) = \frac{1}{\underline{N^e}} \sum_{i=1}^{N^e} \varphi \epsilon \overline{Apr}(c_i^e), \tag{2}$$

By applying these rules, an FR number is formed ($\widetilde{X}_i$), which can be represented as [40]:

$$FR\left(\widetilde{X}_i\right) = \left(\left[x_i^{lL}, x_i^{lU}\right], \left[x_i^{mL}, x_i^{mU}\right], \left[x_i^{uL}, x_i^{uU}\right]\right) = \left(\left[\underline{Lim}\left(x_i^l\right), \overline{Lim}\left(x_i^l\right)\right], \left[\underline{Lim}\left(x_i^m\right), \overline{Lim}\left(x_i^m\right)\right], \left[\underline{Lim}\left(x_i^u\right), \overline{Lim}\left(x_i^u\right)\right]\right), \tag{3}$$

If there are two FR numbers, $FR(\overline{\overline{a}}) = \left(\left[a^{lL}, a^{lU}\right], \left[a^{mL}, \alpha^{mU}\right], \left[a^{uL}, a^{uU}\right]\right)$ and $FR\left(\overline{\overline{b}}\right) = \left(\left[b^{lL}, b^{lU}\right], \left[b^{mL}, b^{mU}\right], \left[b^{uL}, b^{uU}\right]\right)$, then the operations applied on them are [16]:

Addition:

$$FR(\overline{\overline{a}}) + FR\left(\overline{\overline{b}}\right) = \left(\left[a^{lL}, a^{lU}\right], \left[a^{mL}, a^{mU}\right], \left[a^{uL}, a^{uU}\right]\right) + \left(\left[b^{lL}, b^{lU}\right], \left[b^{mL}, b^{mU}\right], \left[b^{uL}, b^{uU}\right]\right) = \left[a^{lL} + b^{lL}, a^{lU} + b^{lU}\right], \left[a^{mL} + b^{mL}, a^{mU} + b^{mU}\right], \left[a^{uL} + b^{uL}, a^{uU} + b^{uU}\right], \tag{4}$$

Subtraction:

$$FR(\overline{\overline{a}}) - FR\left(\overline{\overline{b}}\right) = \left(\left[a^{lL}, a^{lU}\right], \left[a^{mL}, a^{mU}\right], \left[a^{uL}, a^{uU}\right]\right) - \left(\left[b^{lL}, b^{lU}\right], \left[b^{mL}, b^{mU}\right], \left[b^{uL}, b^{uU}\right]\right) = \left[a^{lL} - b^{uU}, a^{lU} - b^{uL}\right], \left[a^{mL} - b^{mU}, a^{mU} - b^{mL}\right], \left[a^{uL} - b^{lU}, a^{uU} - b^{lL}\right], \tag{5}$$

Multiplication:

$$FR(\overline{\overline{a}}) \times FR\left(\overline{\overline{b}}\right) = \left(\left[a^{lL}, a^{lU}\right], \left[a^{mL}, a^{mU}\right], \left[a^{uL}, a^{uU}\right]\right) \times \left(\left[b^{lL}, b^{lU}\right], \left[b^{mL}, b^{mU}\right], \left[b^{uL}, b^{uU}\right]\right) = \left[a^{lL} \times b^{lL}, a^{lU} \times b^{lU}\right], \left[a^{mL} \times b^{mL}, a^{mU} \times b^{mU}\right], \left[a^{uL} \times b^{uL}, a^{uU} \times b^{uU}\right], \tag{6}$$

Division:

$$FR(\overline{\overline{a}}) \div FR\left(\overline{\overline{b}}\right) = \left(\left[a^{lL}, a^{lU}\right], \left[a^{mL}, a^{mU}\right], \left[a^{uL}, a^{uU}\right]\right) \div \left(\left[b^{lL}, b^{lU}\right], \left[b^{mL}, b^{mU}\right], \left[b^{uL}, b^{uU}\right]\right) = \left[a^{lL} \div b^{uU}, a^{lU} \div b^{uL}\right], \left[a^{mL} \div b^{mU}, a^{mU} \div b^{mL}\right], \left[a^{uL} \div b^{lU}, a^{uU} \div b^{lL}\right], \tag{7}$$

When applying these operations, one must take into consideration that the upper limit of the first FR number is not greater than the lower limit of the second FR number. Furthermore, the upper limit of the second FR number should not be greater than the lower limit of the third FR number. However, these values can be the same. If this happens, it is necessary to correct the FR numbers to solve this omission [49].

3.2. Fuzzy–Rough SWARA Method

In the selection a sustainable contractor for the purposes of this study, it was first necessary to determine the importance of weights. For this purpose, FR SWARA was used. The original version of the SWARA method was developed by Keršulienė et al. [50]. It belongs to subjective methods for determining the importance of criteria [51]. This method has seen many applications and modifications since then. In this study, the steps for modifying the FR method in FR form were used. This modified the steps developed by Chen et al. [52] from their study:

Step 1. Determination of the criteria group;

Step 2. Establishing the team of experts;

Step 3. Experts' assessments of the criteria;

Step 4. The transformation of a group FR initial decision matrix coming from individual expert ratings;

Step 5. Ranking criteria;
Step 6. Determining the importance of the criteria by applying normalization:

$$FRN(N_j) = \left[\left(n_j^{L1}, n_j^{U1}\right), \left(n_j^{L2}, n_j^{U2}\right), \left(n_j^{L3}, n_j^{U3}\right)\right]_{1xm} \quad (8)$$

It is important that the criteria values are ordered from largest to smallest;
Step 7. Determining the relative importance of the criteria $FRN(\varphi_j)$:

$$FRN(\varphi_j) = \left[\left(\varphi_j^{L1}, \varphi_j^{U1}\right), \left(\varphi_j^{L2}, \varphi_j^{U2}\right), \left(\varphi_j^{L3}, \varphi_j^{U3}\right)\right]_{1xm} \quad (9)$$

Step 8. Calculation of the converted weight matrix for the criteria $FRN(\vartheta_j)$:

$$FRN(\vartheta_j) = \left[\left(\vartheta_j^{L1}, \vartheta_j^{U1}\right), \left(\vartheta_j^{L2}, \vartheta_j^{U2}\right), \left(\vartheta_j^{L3}, \vartheta_j^{U3}\right)\right]_{1xm} \quad (10)$$

Step 9. Formation of the final weight value:

$$FRN(w_j) = \left[\left(\frac{\vartheta_j^{L1}}{\chi_j^{U3}}, \frac{\vartheta_j^{U1}}{\chi_j^{L3}}\right), \left(\frac{\vartheta_j^{L2}}{\chi_j^{U2}}, \frac{\vartheta_j^{U2}}{\chi_j^{L2}}\right), \left(\frac{\vartheta_j^{L3}}{\chi_j^{U1}}, \frac{\vartheta_j^{U3}}{\chi_j^{L1}}\right)\right] \quad (11)$$

A more detailed explanation of these steps is provided when this method is practically applied.

3.3. Fuzzy–Rough CRADIS Method

The original CRADIS method was introduced by Puška et al. [53]. The purpose of this method is to determine the ranking of alternatives through the deviation of ideal and anti-ideal solutions through the formation of the utility function [54].

The CRADIS method has so far been successfully used in solving problems related to energy, environment, sustainability, supplier selection, etc. [55], which confirms the justification of using this method in the selection of eco-friendly suppliers. This method was created based on the elements of three different multi-criteria analyses, namely ARAS, MARCOS, and TOPSIS [54]. There is something from each of these methods that was incorporated into this method. The specific steps of those methods were not copied, but they were adapted to this method. Thus, the utility function was taken from the ARAS method, the ideal and anti-ideal solution from the MARCOS method, and the deviation was taken from the TOPSIS method. These steps, along with the usual normalization and weighting steps, formed this method. The steps of this method are as follows:

Step 1. Formation of the decision matrix in which experts evaluate alternatives: This is completed based on the criteria.

Step 2. Transformation and formation of the FR decision matrix: Linguistic values are transformed into FR numbers in this step, and a decision matrix is formed from these numbers.

Step 3. Normalization of the FR decision matrix: The formula for calculating the normalization differs according to the criterion type. The criterion can benefit where the alternative should have as much value as possible, and criterion is disadvantaged (cost) where it is better that the alternative has as little value as possible.

$$\bar{\bar{n}}_{ij} = \left(\left[\frac{\alpha^{lL}}{max_i\alpha_i^{uU}} \cdot \frac{\alpha^{lU}}{max_i\alpha_i^{uL}}\right] \cdot \left[\frac{\alpha^{mL}}{max_i\alpha_i^{mU}} \cdot \frac{\alpha^{mU}}{max_i\alpha_i^{mL}}\right] \cdot \left[\frac{\alpha^{uL}}{max_i\alpha_i^{lU}} \cdot \frac{\alpha^{uU}}{max_i\alpha_i^{lL}}\right]\right), \text{benefit} \quad (12)$$

$$\bar{\bar{n}}_{ij} = \left(\left[\frac{\min x_j^{lL}}{x_{ij}^{uU}}, \frac{\min x_j^{lU}}{x_{ij}^{uL}}\right], \left[\frac{\min x_j^{mL}}{x_{ij}^{mU}}, \frac{\min x_j^{mU}}{x_{ij}^{mL}}\right], \left[\frac{\min x_{ij}^{uL}}{x_{ij}^{lU}}, \frac{\min x_j^{uU}}{x_{ij}^{lL}}\right]\right), \text{cost} \quad (13)$$

Step 4. Aggravation of the normalized FR decision matrix: In this step, the value of the normalized FR numbers is multiplied with the appropriate weight of the criteria.

$$\bar{\bar{v}}_{ij} = \bar{\bar{w}}_j \cdot \bar{\bar{n}}_{ij} \tag{14}$$

Step 5. Determination of ideal and anti-ideal values: The ideal value is the maximum value in all FR numbers, while the anti-ideal value is the smallest value.

$$\bar{\bar{t}}_i = \max \bar{\bar{v}}_{ij},\ \text{where}\ \bar{\bar{v}}_{ij} = \left(\left[v^{lL}, v^{lU} \right], \left[v^{mL}, v^{mU} \right], \left[v^{uL}, v^{uU} \right] \right) \tag{15}$$

$$\bar{\bar{t}}_{ai} = \min \bar{\bar{v}}_{ij},\ \text{where}\ \bar{\bar{v}}_{ij} = \left(\left[v^{lL}, v^{lU} \right], \left[v^{mL}, v^{mU} \right], \left[v^{uL}, v^{uU} \right] \right) \tag{16}$$

Step 6. Calculation of deviations from ideal and anti-ideal values: This deviation from all values of the difficult FR decision matrix is calculated.

$$\bar{\bar{d}}^{+} = \bar{\bar{t}}_i - \bar{\bar{v}}_{ij}, \tag{17}$$

$$\bar{\bar{d}}^{-} = \bar{\bar{v}}_{ij} - \bar{\bar{t}}_{ai} \tag{18}$$

Step 7. Formation of optimal alternatives: The optimal alternatives are the alternative values with the smallest deviation ($\bar{\bar{s}}_0^{+}$) from the ideal value, and the largest deviation from the anti-ideal value ($\bar{\bar{s}}_0^{-}$).

Step 8. Determining the total variances of alternatives from ideal and anti-ideal values:

$$\bar{\bar{s}}_i^{+} = \sum_{j=1}^{n} \bar{\bar{d}}^{+}, \tag{19}$$

$$\bar{\bar{s}}_i^{-} = \sum_{j=1}^{n} \bar{\bar{d}}^{-}, \tag{20}$$

Step 9. Calculation of the utility function:

$$\bar{\bar{K}}_i^{+} = \frac{\bar{\bar{s}}_0^{+}}{\bar{\bar{s}}_i^{+}} = \left(\left[\frac{s_0^{+lL}}{s_i^{+uU}} \cdot \frac{s_0^{+lU}}{s_i^{+uL}} \right] \cdot \left[\frac{s_0^{+mL}}{s_i^{+mU}} \cdot \frac{s_0^{+mU}}{s_i^{+mL}} \right] \cdot \left[\frac{s_0^{+uL}}{s_i^{+lU}} \cdot \frac{s_0^{+uU}}{s_i^{+lL}} \right] \right), \tag{21}$$

$$\bar{\bar{K}}_i^{+} = \frac{\bar{\bar{s}}_0^{+}}{\bar{\bar{s}}_i^{+}} = \left(\left[\frac{s_0^{+lL}}{s_i^{+uU}} \cdot \frac{s_0^{+lU}}{s_i^{+uL}} \right] \cdot \left[\frac{s_0^{+mL}}{s_i^{+mU}} \cdot \frac{s_0^{+mU}}{s_i^{+mL}} \right] \cdot \left[\frac{s_0^{+uL}}{s_i^{+lU}} \cdot \frac{s_0^{+uU}}{s_i^{+lL}} \right] \right), \tag{22}$$

Step 10. Ranking of alternatives:

$$\bar{\bar{Q}}_i = \frac{\bar{\bar{K}}_i^{+} + \bar{\bar{K}}_i^{+}}{2}, \tag{23}$$

Step 11. Transformation into crips value of CRADIS method results:

$$R_i = \frac{Q_i^{lL} + Q_i^{lU} + Q_i^{mL} + Q_i^{mU} + Q_i^{uL} + Q_i^{uU}}{6}, \tag{24}$$

The alternative with the highest value is the best one, and the alternative with the lowest value is the worst.

4. Case Study

To examine the effectiveness of the FR approach using the SWARA and CRADIS methodologies, the company Voćar (Gornji Rahić 112, City of Brčko, Bosnia and Herzegovina) was chosen as the case study subject. This company has more than 30 years of experience in food production. They produce a variety of products, from dried fruits to various sprinkles, nuts and grains, chocolates, spreads, and various other food products.

As part of the EU4AGRI project, this company procured solar panels for the production of renewable energy, so it was necessary to install these solar panels. The planned total power of this solar power plant is 150 kW of electricity. The reason why this company decided to implement this project is to reduce production costs, because more energy is consumed in production. In addition, this solar power plant will contribute to the protection of the environment, and at the same time, contribute to energy independence in the operations of this company.

The selection of contractors in this study was conducted using expert decision making. Voćar requested the author of this paper to support the company in making the right choice based on the scientific approach. The reason for conducting this study was due to differences in opinions within the company about the right selection of a contractor; thus, external assistance was an alternative to making an appropriate selection that would accommodate different decision criteria and different views on the importance of these criteria for the company.

Based on the author's proposal, the company identified five experts to select a sustainable supplier. Since it was a specific company project, they decided to hire two of their employees as experts and three expert advisors from construction and electrical engineering to select a suitable contractor. The reason why external experts were hired is because of the specific knowledge that these experts possess. These hired external experts are, in fact, professional associates of the company Voćar. They perform, as necessary, work related to electrical installations and construction, but they do not install solar panels themselves. This company signed a cooperation agreement with them, so they were hired to help this company with the selection of contractors. The experts were in charge of providing their opinions about the criteria and alternatives, while the author of this paper conducted scientific analyses based on the selected FR methods. The reason for the application of the FR approach was to deal with uncertainty and imprecise information related to different criteria, for which the company decision makers had different opinions. It also enabled the integration of principles from different multi-criteria decision-making models.

The employees from Voćar that took part in the survey were the executive director of the company and the chief technologist. Since these persons do not have sufficient knowledge about the selection of contractors, three experts from the field of construction and electrical engineering were hired to provide subject matter expertise, while the author of this paper was responsible for creating the framework, conducting the analysis, and interpreting the results. Construction experts were hired to provide expertise for the construction of solar panels, and an electrical engineering expert provided his expertise for the production of electricity from solar panels. Together, they analyzed each of the identified contractors, provided ratings on the importance of certain criteria and evaluated the contractors using those criteria.

To install the solar panels, it was necessary to engage contractors who could perform all the preparatory work for the installation of the panels, as well as the installation of the panels themselves. Because of the project itself and the desire of the company to implement ecologically acceptable production, they decided to consider sustainability in the selection of contractors. In total, they took six potential contractors into consideration. These contractors were from the country of Bosnia and Herzegovina and spatially closer to the headquarters of this company. During the analysis of these potential contractors, a total of 18 criteria were applied, which were part of the environmental, economic, and social criteria (Table 2). These sustainability criteria were thus symmetrically divided into the same number of subsidiary criteria in order to give equal importance to all criteria. These criteria were equally distributed in the main criteria, so that none of these criteria were additionally emphasized. The specificity of these criteria was that they were adapted to the selection of green contractors. Table 2 shows how the main sustainability criteria are divided into auxiliary criteria, and descriptions of the importance of these criteria are given. These criteria were selected based on a previous review of the literature; that is, the mentioned studies were used to form these criteria. Some of the studies had greater and others little merit in determining these criteria.

Table 2. Research criteria.

Id	Criteria	Description	Reference
C1	Environmental criteria		
C11	Business sustainability	Application of sustainable practices in business	[24,27]
C12	Certified accreditation in environmental management	Availability of certificates through EMS management	[21,23]
C13	The use of sustainable technologies	Application of sustainable technologies to realize a sustainable construction project	[19,23]
C14	Waste management	Implementation of waste reduction and reuse	[20,23]
C15	Energy efficiency	Measures and technologies that reduce energy consumption during project implementation	[8,22]
C16	Green technology	The use of green technologies in construction to minimize the effect on the environment	[23,24]
C2	Economic criteria		
C21	Capacity of the contractor	Technical capacities available to the contractor	[24,28]
C22	Experience	Previous experience with similar projects	[24,26,30]
C23	Financial stability	Contractor's ability to maintain liquidity and cover operating costs during the execution of the project	[20,26,30]
C24	Price for implementation	Monetary value of project works	[19,20,30]
C25	Quality of implementation	Satisfying the needs of clients through the fulfillment of high standards in construction	[7,26,30]
C26	Time for implementation	Respecting the agreed deadlines for project implementation	[19,26,30]
C3	Social criteria		
C31	Safety performance	Procedures for the safety of workers at work	[19,23,26]
C32	Employee skills	Expertise and ability of the employee to perform the work successfully	[20,22,26]
C33	Stability of business	Reduced employee turnover from the company	[22,28]
C34	Ethical standards	Transparency in business and respect for legal and social norms	[24,28]
C35	Reputation	The market's perception of the reliability and quality of the work performed through the fulfillment of client expectations	[20,23,30]
C36	The rights of workers	Compliance with legal norms, fair employment conditions, and opportunities for professional development	[24,28,29]

4.1. Model Implementation and Results Analysis

After the criteria were identified and the contractors and experts were determined, the experts evaluated the criteria first and then the selected contractors. Since the criteria were divided into three groups, and each of these groups had its own auxiliary criteria, the main criteria were evaluated first followed by the auxiliary criteria. Using the example of the main criteria, the procedure for obtaining the weights with the FR SWARA method is explained further.

The first step in obtaining the weights of the criteria is the evaluation of the criteria by experts (Table 3). In this step, the experts evaluate the importance of the criteria according to their opinions using linguistic values (Table 1). If, according to experts' opinions, a certain criterion is more important, a higher linguistic value will be given and vice versa.

Table 3. Experts' assessments on the main criteria.

Experts	C1	C2	C3
Expert 1	G (2, 3, 4)	VG (1, 1, 2)	G (2, 3, 4)
Expert 2	MG (3, 4, 5)	MG (3, 4, 5)	MG (3, 4, 5)
Expert 3	VG (1, 1, 2)	G (2, 3, 4)	G (2, 3, 4)
Expert 4	MG (3, 4, 5)	G (2, 3, 4)	MG (3, 4, 5)
Expert 5	G (2, 3, 4)	G (2, 3, 4)	VG (1, 1, 2)

In the second step, the transformation of linguistic values into equivalent fuzzy numbers is carried out. The transformation is performed using the function of membership of the linguistic value to the adequate fuzzy number (Table 1). Using this function, the "very good" value is represented as a fuzzy number (1, 1, 2), and the "good" value as a fuzzy number (2, 3, 4). This process transforms all linguistic values into matching fuzzy numbers. The next stage of the process is to determine the rough number's upper and lower limits. The rules for determining rough numbers from fuzzy numbers are as follows:

- When determining the lower limit of the FR number for each expert, the value given by an individual expert is observed first, followed by the values of other experts. The expert values that are the same or less than the observed expert's value are taken, and the sum of these values is divided by the total number of values.
- When determining the upper limit of the FR number, the value of the observed expert is also looked at first, and then the values of other experts that are greater or the same as the value of the observed expert are looked at. Those values are taken and divided by the number of values. In this way, lower and upper limits are formed for all experts. It should be noted that the lower and upper limits of the FR number are determined for each individual fuzzy number.

This procedure for expert 1 is explained using the example of the main criterion:

$$C_1^{lL} = \frac{2+1+2}{3} = 1.67;\ C_1^{lU} = \frac{2+3+3+2}{4} = 2.50;$$

$$C_1^{mL} = \frac{3+1+3}{3} = 2.33;\ C_1^{mU} = \frac{3+4+4+3}{4} = 3.50;$$

$$C_1^{uL} = \frac{4+2+4}{3} = 3.33;\ C_1^{uU} = \frac{4+5+5+4}{4} = 4.50.$$

Finding the lower and upper limits of the rough number was achieved by looking at an individual expert and looking at their fuzzy numbers as well as the numbers of other experts. For the lower limit, the same values and less are taken, and for the upper limit, the same values and higher than the values for that expert are taken. Applying this principle, the initial FR decision matrix is formed, which is the basis for calculating the FR SWARA method (Table 4).

Table 4. Initial decision matrix for main criteria.

	C1	C2	C3
E1	([1.67, 2.50][2.33, 3.50][3.33, 4.50])	([1.00, 2.00][1.00, 2.80][2.00, 3.80])	([1.67, 2.50][2.33, 3.50][3.33, 4.50])
E2	([2.20, 3.00][3.00, 4.00][4.00, 5.00])	([2.00, 3.00][2.80, 4.00][3.80, 5.00])	([2.20, 3.00][3.00, 4.00][4.00, 5.00])
E3	([1.00, 2.20][1.00, 3.00][2.00, 4.00])	([1.75, 2.25][2.50, 3.25][3.50, 4.25])	([1.67, 2.50][2.33, 3.50][3.33, 4.50])
E4	([2.20, 3.00][3.00, 4.00][4.00, 5.00])	([1.75, 2.25][2.50, 3.25][3.50, 4.25])	([2.20, 3.00][3.00, 4.00][4.00, 5.00])
E5	([1.67, 2.50][2.33, 3.50][3.33, 4.50])	([1.75, 2.25][2.50, 3.25][3.50, 4.25])	([1.00, 2.20][1.00, 3.00][2.00, 4.00])
A	([1.75, 2.64][2.33, 3.60][3.33, 4.60])	([1.65, 2.35][2.26, 3.31][3.26, 4.31])	([1.75, 2.64][2.33, 3.60][3.33, 4.60])

To obtain results that represent experts' evaluations, the FR SWARA method was modified. First, the average value of the FR number for the experts was calculated, and these values were ranked from the smallest to the largest value. The smallest value of the FR number has criterion C2, followed by criteria C1 and C3, which have the same value. Therefore, these two criteria must be given the same weight, since they have the same value, while the value of criterion C2 is slightly less than the value of these two criteria. The next step was to find the highest value for all criteria, which are the values of criteria C1 and C3. Then, each individual criterion was divided by the maximum value of the FR number. In this way, the normalized values of the FR number were obtained for each criterion (8). Then, the relative importance value of the criteria was formed as follows: The criterion that had the smallest normalized value was also assigned the value of one for all FR numbers. Then, the values for the other criteria were formed in such a way that the normalized values of those criteria were subtracted from the value of the criterion that has the highest value, and one was added to that value. This was completed for all criteria values. Then, the values of the recalculated criteria matrix were formed by rewriting the value of one for the criterion that had the lowest value. For other criteria, this value was formed by dividing it by all units of the real value of the other criteria. Then, all the values of these recalculated criteria were added up, and the individual values of all criteria were divided by this total value, and the final weight of the criteria was formed.

In this way, criteria C1 and C3 received the same weight value, which was less than the weight of criterion C2, which received the best marks from all experts (Table 5). In addition, the values of these weights did not deviate too much, just as the linguistic values of the experts did not deviate too much for all criteria.

Table 5. Weight values for the main criteria using the FR SWARA method.

	FRN $\left(\varphi_j\right)$	**FRN** $\left(\vartheta_j\right)$	**FRN** $\left(w_j\right)$
C2	([1.00, 1.00][1.00, 1.00][1.00, 1.00])	([1.00, 1.00][1.00, 1.00][1.00, 1.00])	([0.34, 0.35][0.35, 0.36][0.36, 0.37])
C1	([1.02, 1.08][1.08, 1.11][1.11, 1.17])	([0.86, 0.90][0.90, 0.93][0.93, 0.98])	([0.29, 0.32][0.32, 0.33][0.33, 0.36])
C3	([1.02, 1.08][1.08, 1.11][1.11, 1.17])	([0.86, 0.90][0.90, 0.93][0.93, 0.98])	([0.29, 0.32][0.32, 0.33][0.33, 0.36])
		([2.72, 2.80][2.80, 2.85][2.85, 2.96])	

The same method was used to calculate the values for the auxiliary criteria. First, the experts evaluated the importance of various auxiliary criteria for the contractor selection process using linguistic values (Table 6).

Table 6. Evaluation of auxiliary criteria by experts.

	C11	**C12**	**C13**	**C14**	**C15**	**C16**	**C21**	**C22**	**C23**	**C24**	**C25**	**C26**	**C31**	**C32**	**C33**	**C34**	**C35**	**C36**
E1	VG	MG	G	MG	F	MG	G	VG	G	G	VG	G	G	VG	MG	G	VG	MG
E2	G	G	G	MG	MG	G	VG	VG	MG	G	G	MG	MG	G	G	VG	VG	G
E3	VG	MG	MG	G	F	G	G	G	MG	G	G	MG	MG	VG	G	G	VG	MG
E4	G	MG	G	MG	F	MG	VG	VG	G	VG	VG	G	G	VG	MG	G	G	MG
E5	VG	G	MG	MG	MG	G	G	VG	MG	G	VG	MG	G	VG	MG	VG	VG	MG

These values were then transformed into FR numbers in the same way as with the main criteria. The steps of the FR SWARA method were then applied, and weights were formed for all auxiliary criteria. The final weights were formed by multiplying the values of the main criteria with the corresponding auxiliary criteria (Table A1).

After the weights of the criteria were calculated, the calculation determined which of the contractors, according to the experts' evaluations, best met the selected criteria. Until the first FR decision matrix was produced, the steps were the same. So first, the selected contractors were evaluated by the experts for the observed criteria using linguistic values (Table 7).

Table 7. Evaluation of contractors by experts.

E1	C11	C12	C13	C14	C15	C16	C21	C22	C23	C24	C25	C26	C31	C32	C33	C34	C35	C36
C1	F	MG	MG	G	F	MG	F	MG	F	MG	MG	F	MG	F	G	F	MG	F
C2	MG	F	F	MG	F	MG	MP	MG	F	MP	F	MP	F	MG	MP	F	MG	F
C3	G	G	MG	VG	G	VG	G	G	G	VG	G	G	G	G	G	MG	G	MG
C4	F	MG	F	G	MG	MG	F	G	G	G	MG	F	MG	G	F	G	MG	G
C5	F	MG	MG	F	G	F	MG	MG	VG	MG	VG	MG	MG	G	G	MG	VG	MG
C6	G	MG	G	MG	G	MG	G	MG	VG	G	G	G	VG	MG	VG	G	MG	VG
E2	C11	C12	C13	C14	C15	C16	C21	C22	C23	C24	C25	C26	C31	C32	C33	C34	C35	C36
C1	F	MG	F	F	MG	G	MG	MG	F	F	MG	MG	F	MG	MG	MG	MG	MG
C2	F	F	F	MG	F	F	F	G	F	F	MG	F	MG	MG	MP	MG	MG	MG
C3	G	G	G	VG	VG	G	MG	VG	MG	G	MG	VG	G	VG	G	G	VG	G
C4	F	MG	MG	MG	F	G	MG	MG	MG	MG	MG	MG	MG	MG	MG	MG	MG	G
C5	F	MG	G	MG	MG	MG	G	G	G	G	VG	G	MG	MG	MG	G	G	G
C6	VG	G	VG	MG	G	MG	VG	G	VG	G	VG	MG	G	G	G	VG	G	VG
E3	C11	C12	C13	C14	C15	C16	C21	C22	C23	C24	C25	C26	C31	C32	C33	C34	C35	C36
C1	MG	F	F	G	MG	MG	MG	MG	F	F	G	MG	MG	MG	MG	MG	F	MG
C2	F	MP	MP	MG	F	F	F	MG	MG	F	F	MP	MG	MG	MP	MG	MG	MG
C3	MG	VG	G	G	G	G	MG	VG	MG	G	MG	VG	MG	G	G	G	VG	MG
C4	F	G	MG	MG	MG	G	MG	G	MG	MG	G	MG	MG	G	MG	MG	MG	MG
C5	F	G	MG	MG	MG	MG	G	MG	VG	G	G	G	F	MG	MG	MG	G	G
C6	VG	G	VG	G	G	G	VG	G	G	VG	VG	MG	VG	G	G	G	G	G
E4	C11	C12	C13	C14	C15	C16	C21	C22	C23	C24	C25	C26	C31	C32	C33	C34	C35	C36
C1	F	F	MG	MG	F	MG	F	F	MG	F	MG	G	MG	F	G	F	MG	MG
C2	F	F	MP	MG	F	MG	F	MG	MG	F	MG	MP	MG	F	F	F	G	F
C3	G	G	G	G	G	G	G	G	G	G	G	VG	G	G	VG	G	VG	MG
C4	MG	MG	F	G	MG	MG	MG	MG	G	G	G	MG	G	MG	G	G	G	MG
C5	MG	MG	MG	MG	MG	MG	G	G	VG	G	G	MG	F	G	MG	G	VG	MG
C6	VG	G	G	G	G	G	VG	G	VG	VG	G	G	G	G	VG	VG	G	G
E5	C11	C12	C13	C14	C15	C16	C21	C22	C23	C24	C25	C26	C31	C32	C33	C34	C35	C36
C1	MG	MG	MG	MG	MG	MG	F	MG	F	MG	MG	MG	MG	F	MG	MG	F	F
C2	MG	F	F	F	MP	MG	MP	G	F	MP	F	F	MG	F	MP	F	G	F
C3	MG	G	MG	VG	VG	VG	G	G	G	G	G	G	MG	VG	G	G	G	MG
C4	MG	MG	MG	MG	F	MG	F	MG	G	G	MG	MG	G	G	G	G	MG	MG
C5	F	G	G	F	G	MG	G	G	G	G	VG	G	MG	G	G	G	VG	G
C6	G	MG	G	G	VG	G	G	G	VG	G	VG	G	VG	MG	VG	G	MG	VG

Following the transformation of these linguistic values into matching fuzzy numbers (Table 1), the upper and lower limits were determined using the same methodology as the FR SWARA approach. Following this, an initial summary of the FR decision matrix was created, serving as the foundational matrix for determining the FR CRADIS method's value. The first step of the FR CRADIS method is normalization. Since linguistic values are in the form of "very poor" to "very good", all criteria were viewed in the form of benefit criteria. That is why the expression for the benefit criteria (12) was applied in the normalization. First, all the maximum values for individual criteria were found, and then the individual values of the FR decision matrix were divided by the corresponding values. For criterion C11 and alternative A1, this is how it was accomplished:

$$r_{11} = \left[\frac{4.2}{9.7} = 0.43; \frac{4.6}{8.7} = 0.53\right]\left[\frac{5.2}{8.7} = 0.59; \frac{5.6}{7.7} = 0.73\right]\left[\frac{6.2}{7.7} = 0.80\ ; \frac{6.6}{6.7} = 0.99\right]$$

In the same way, normalized values were calculated, and the initial normalized FR decision matrix was formed. The next step is about aggravating decision matrix. This was achieved by multiplying each element of the normalized decision matrix by the corresponding weight. In the same example, it looks like this:

$$v_{11} = [0.43 \cdot 0.06 = 0.02; 0.53 \cdot 0.06 = 0.03]\ [0.59 \cdot 0.07 = 0.04; 0.73 \cdot 0.07 = 0.05]\ [0.80 \cdot 0.08 = 0.06\ ; 0.99 \cdot 0.09 = 0.09]$$

Following the aggravation of the decision matrix, the ideal and anti-ideal solutions, or maximum and minimum values, were computed from this matrix. Following this, the cumulative deviation concerning the ideal and non-ideal solutions was computed, along with the deviations from these values. Based on these cumulative deviations, the utility function was also calculated in relation to these deviations. This was accomplished by first determining the optimal alternatives (Table 8).

Table 8. Cumulative deviations from ideal and anti-ideal solutions and utility functions.

C	$\bar{\bar{s}}_i^+$	$\bar{\bar{s}}_i^-$	$\bar{\bar{K}}_i^+$	$\bar{\bar{K}}_i^-$
C1	([0.86,1.21][1.40,1.62][1.74,1.87])	([0.19,0.31][0.44,0.66][0.85,1.20])	([0.19,0.50][0.65,0.99][1.24,1.98])	([0.11,0.27][0.43,0.98][1.51,3.34])
C2	([0.95,1.27][1.46,1.66][1.78,1.90])	([0.16,0.28][0.39,0.60][0.79,1.11])	([0.19,0.49][0.63,0.95][1.18,1.80])	([0.09,0.23][0.39,0.90][1.39,3.10])
C3	([0.53,0.98][1.17,1.46][1.58,1.75])	([0.31,0.48][0.60,0.89][1.08,1.53])	([0.21,0.56][0.72,1.19][1.53,3.21])	([0.18,0.41][0.59,1.33][1.92,4.26])
C4	([0.76,1.13][1.33,1.57][1.70,1.83])	([0.23,0.36][0.49,0.73][0.93,1.29])	([0.20,0.52][0.67,1.04][1.32,2.22])	([0.14,0.31][0.48,1.09][1.64,3.60])
C5	([0.68,1.07][1.27,1.52][1.65,1.79])	([0.27,0.41][0.54,0.79][0.99,1.38])	([0.20,0.53][0.69,1.10][1.40,2.51])	([0.16,0.35][0.53,1.19][1.76,3.85])
C6	([0.49,0.95][1.14,1.44][1.56,1.74])	([0.32,0.50][0.62,0.92][1.11,1.57])	([0.21,0.56][0.73,1.22][1.58,3.50])	([0.19,0.42][0.61,1.38][1.97,4.38])
C_0	([0.36,0.88][1.05,1.39][1.49,1.70])	([0.36,0.56][0.67,1.01][1.18, 1.70])		

These are the alternatives that have the lowest or highest value for each alternative. When deviating from the ideal solution, this alternative is smaller than other alternatives, while when deviating from the anti-ideal solution, this alternative is greater than the other alternatives. By applying these alternatives, utility functions can be calculated, which are the basis for forming the final ranking of the alternatives.

The last steps of the FR CRADIS method are to rank the alternatives and convert that number into a Crips number. This was achieved by averaging the utility functions (Table 9).

Table 9. Results of ranking with FR CRADIS method.

C	$\bar{\bar{Q}}_i$	R_i	RANK
C1	([0.15, 0.38][0.54, 0.99][1.38, 2.66])	1.017	5
C2	([0.14, 0.36][0.51, 0.92][1.29, 2.45])	0.945	6
C3	([0.19, 0.48][0.66, 1.26][1.72, 3.73])	1.341	2
C4	([0.17, 0.41][0.58, 1.06][1.48, 2.91])	1.102	4
C5	([0.18, 0.44][0.61, 1.14][1.58, 3.18])	1.188	3
C6	([0.20, 0.49][0.67, 1.30][1.77, 3.94])	1.397	1

Based on this result, it can be seen that the best ranked contractor is C6, followed by C3, while the worst ranked contractor is C2. To confirm this ranking, a comparison was made with the results of other FR methods. In addition, a sensitivity analysis was carried out in order to determine whether any of the individual auxiliary criteria affect the change in the ranking order of the contractors.

4.2. Comparative and Sensitivity Analysis

When conducting a comparative analysis, the same initial FR decision matrix and the same weights were taken, only the ranking with conducted using other multi-criteria methods. This analysis has become regular in studies in which these methods are applied [56]. The goal of this analysis is to determine if the steps applied from different FR methods result in a different ranking order of contractors. For this purpose, six FR methods were used: SAW, ARAS, CoCoSo, MABAC, WPM, and WASPAS. The reason these methods were used are as follows: The SAW method is the simplest method and the easiest to calculate, and its results do not deviate significantly from other methods. The ARAS method uses a different normalization than the CRADIS method, and at the same time, it is a simpler method that has only one step more than the SAW method. The

CoCoSo and MABAC methods use a different normalization compared to CRADIS and ARAS, and the application of these methods is to determine whether the normalization used in certain methods affects different ranking orders. The WPM and WASPAS methods use the same normalization as CRADIS. The WPM method belongs to simple multi-criteria methods like SAW and has the same steps as this method. The WASPAS method actually makes a compromise between the two simplest multi-criteria methods. The results of the application of these methods show that all methods gave the same ranking order as the FR CRADIS method and that there is symmetry in these results. In this way, the results confirmed that contractor C6 shows the best results and is the first choice for the installation of solar panels at the company Voćar (Figure 2).

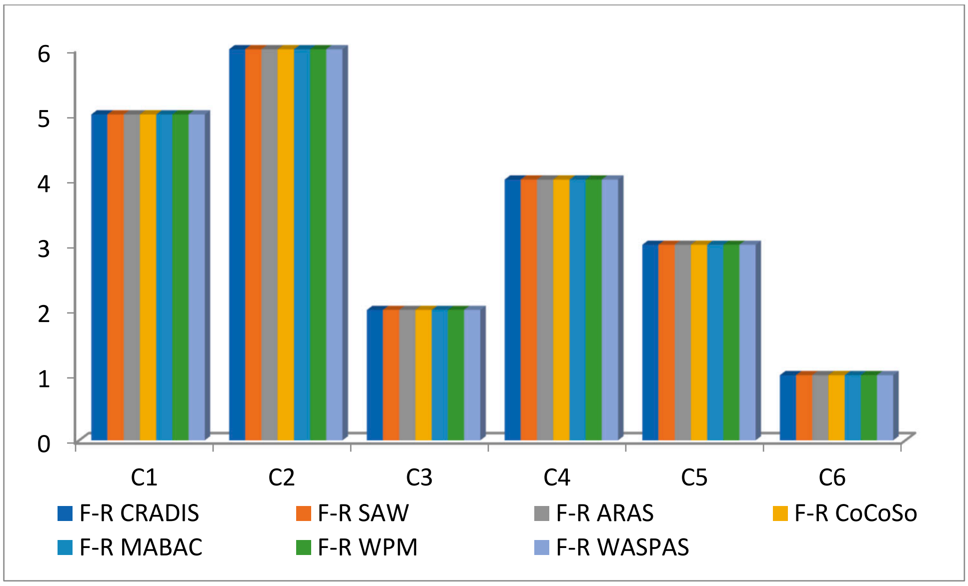

Figure 2. Results of comparative analysis of different F-R methods.

The comparative analysis was followed by a sensitivity analysis. Changing the weights of the criteria and determining how this weight change impacts the final ranking of the alternatives was the intent of this analysis. [57]. In this way, it can be determined how a particular criterion affects how the alternatives are ranked [58]. In this sensitivity analysis, the approach of reducing individual criterion weights by 30% was applied, i.e., each criterion was reduced three times, and a total of 54 scenarios were applied. The goal of this analysis was to analyze how much influence individual auxiliary criteria had on the ranking of contractors. After conducting 54 rankings with these scenarios, it was shown that individual criteria do not change the ranking order of contractors (Figure 3). This shows us that several criteria must be changed at once in order to change the ranking order.

Since the sensitivity analysis showed that individual criteria do not affect the ranking of contractors, another sensitivity analysis was conducted. In this analysis, all individual criteria within the same criterion were given the same importance, while other criteria were taken into consideration. In this way, how the main criteria affect the formation of the ranking order was examined. The results of this sensitivity analysis show that considering only environmental criteria, the best-ranked contractor is C3, while for economic and social criteria, it is contractor C6 (Figure 4). This sensitivity analysis shows that there is still a difference in ranking when looking at a particular main criterion. Thus, contractor C3 has better results in auxiliary environmental criteria, while contractor C6 has better results in in auxiliary economic and social criteria. Therefore, when all these criteria are observed, contractor C6 provides better results.

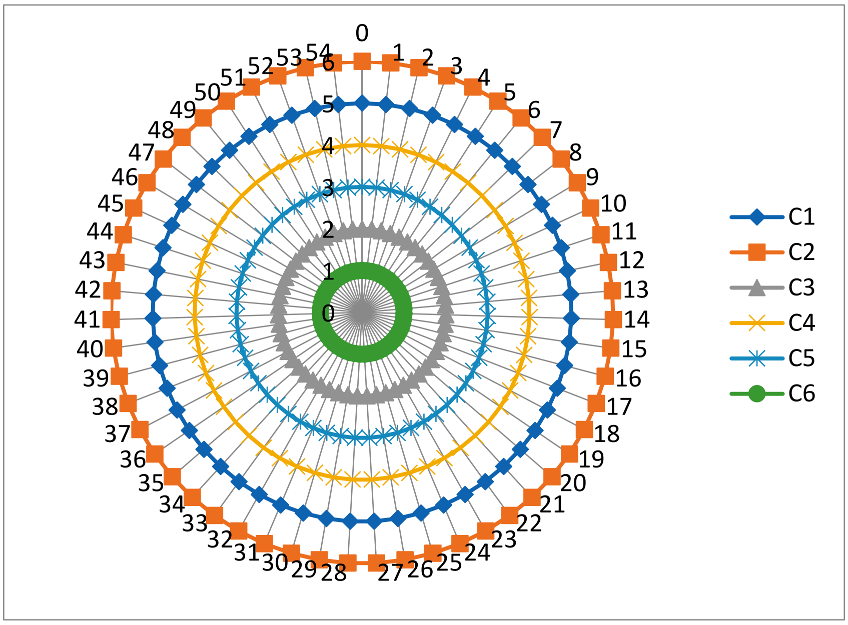

Figure 3. Results of the sensitivity analysis.

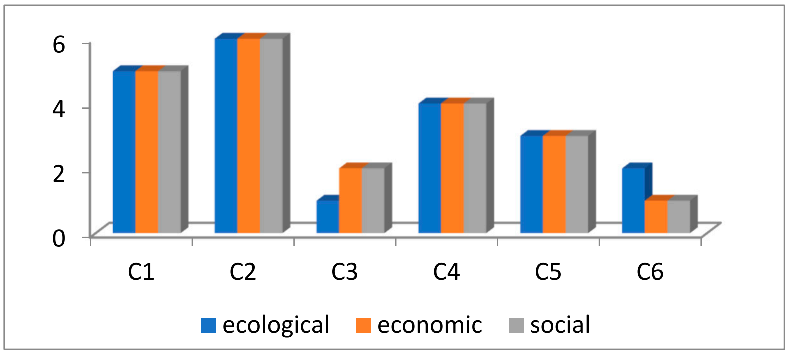

Figure 4. Results of the ranking using the main criteria.

5. Discussion

Many companies invest in the installation of solar panels for energy production from renewable sources as a way to minimize their impact on the environment while reducing production costs [59]. Companies strive to provide as much energy as possible from renewable sources [60], and to do so, they use various resources for the production of electricity [61,62]. Based on this, the company Voćar is also trying to use EU funds to ensure the production of electricity from renewable energy sources. This company decided to install solar panels that ensure the production of 150 kW of electricity. In this way, Voćar will provide up to 70% of its energy using these solar panels. However, to realize this project, it is necessary to hire contractors who can install these panels.

When selecting a contractor, one must choose the criteria that best evaluate these contractors. Therefore, a selection approach based on sustainability was used in this study, where the main criteria are related to environmental, economic, and social aspects. By applying this to the selection of contractors, the contractor who best met these sustainability criteria was selected. The reason why this approach was taken is that the company Voćar is aiming to reduce its impact on the environment, and therefore, has decided to install solar panels. During the installation of the panels, the contractor must respect environmental standards [63], and in addition, take care of his/her employees and have the appropriate capacities that allow them to finish the project on time. Therefore, the sustainability criteria are further divided into subsidiary criteria that further define these main criteria. To give equal importance to each of the basic sustainability criteria, it was decided that these criteria have the same number of auxiliary criteria. This approach is also present in other studies, where either suppliers or contractors were chosen [64,65]. However, this approach is not applied in research, especially when it comes to the selection of contractors [7,66].

To apply this approach to the selection of contractors, expert decision making was used. In this study, to get closer to human thinking, linguistic values were used [67], which are easier to decide compared to classic numerical ratings. In addition, group decision making was used in this study. The company Voćar included five experts in the group decision making: two internally employed by the company and three externally hired experts with experience in construction and electrical engineering. The reason for this is the specificity of this project, which includes construction and electrical works. After this, the experts evaluated the importance of the criteria and the selected contractors according to the selected criteria. Due to this approach, the evaluations given by the experts were more consistent than they would have been if each of these experts separately evaluated both the criteria and the contractors. This is because you cannot have perfect information when making decisions, so decision making was based on incomplete information. To use this information when determining the weights of the criteria and sources of contractors, a fuzzy approach was used. However, a rough approach was added to this approach, which enabled the inclusion of uncertainty in the decision making and helped reduce the subjectivity of the experts during decision making.

Using this approach, the experts first determined the importance of the criteria: first the main criteria and then the auxiliary criteria. In order to determine this importance, the weights of these criteria were calculated using the FR SWARA method. However, this study did not use the FR SWARA method as presented in the papers of Chen et al. [52] and Wang et al. [68]. In this study, this method was modified to simplify its use, and in addition, to allow the weights to better represent the evaluations of the experts. The ratings given by the experts first for the main criteria and then for the auxiliary criteria ranged from "fair" to "very good". Therefore, the final weights could not differ significantly, but had to be approximately equal. Thus, the environmental criterion was rated the best for the main criterion, while the economic and social criteria received the same importance; that is, for these two criteria, the experts' evaluations were the same. Thus, these two criteria received a weight that was ten percent less than the weight of the environmental criterion. In this way, it was shown that this approach respects the evaluations of experts, and as such, gives the weights as represented by these evaluations. In addition, this approach simplified the application of the FR SWARA method, and at the same time, opened the possibility for the creation of new approaches and new methods.

In addition to the new modification of the FR SWARA method, this study also offered an adaptation of the CRADIS method using the FR approach. This paper offered an elaboration of the method adapted to this approach, which is another contribution of this study. By applying this method, it was shown that the best results were achieved by contractor C6, followed by C3, and the worst results were shown by contractor C2. These results were confirmed using a comparative analysis and sensitivity analysis. These two analyses showed that the ranking order of contractors does not change regardless of which FR methods are used and which weights are used for individual criteria. This is true especially when all auxiliary criteria are used. The reason for this should be sought through the group decision-making process that was used in this research. However, using only the auxiliary criteria of a certain main criterion, it was shown that contractor C3 performed better in the environmental criteria than contractor C6. All these analyses, when taken into consideration when making the final decision, show that contractor C6 is the first choice for the installation of solar panels for the company Voćar and could help in the realization of this project. On the basis of this result, the research question was answered. The answer is that contractor C3 could best assist the company Voćar to increase its energy independence by installing a solar power plant.

The obtained results were confirmed through a comparison with other FR methods. Six other methods were used in this analysis. These methods were chosen because of the normalization they perform and because of the specific steps of these methods. However, in this analysis, not all methods are used, but certain methods are selected. A combination of new and old methods was used in this study. Newer methods were used to carry out their processes, and older methods were used to confirm the results. That is why some of the methods, such as TOPSIS, VIKOR, PROMETHEE, ELECTRE, EDAS, and various others, were not used. Since these seven methods gave the same results, there was no need to expand this analysis with the aforementioned methods. In future research, it could be examined whether the results obtained using the FR CRADIS method differ from these aforementioned methods or from some other methods that exist in practice.

6. Conclusions

This study has shown the way in which a contractor can be selected during the implementation of the construction phase of a project. Every company, including Voćar, does not have all the necessary qualifications and capacity to perform all the necessary project work, as in this case, the construction work. Therefore, it was necessary to outsource construction contractors for the purposes of this study. The company Voćar does not perform construction work in its business but engages construction companies during the execution of this work. In this case, due to the specificity of the project realized by this construction company, it must have other professional employees at its disposal. The same reason was used in the selection of experts for this study. For this reason, Voćar hired three external experts. The five experts first evaluated the criteria and then the alternatives using linguistic values. To use these values to obtain results, this study used the FR approach together with the SWARA and CRADIS methods. The results of the SWARA method showed that according to experts' assessments, the most important main criterion is the environmental criterion. Then, by applying the CRADIS method, it was shown that of the six contractors, the best results were shown by contractor C6, who is the first choice for the implementation of this project. This approach used in this research contributed the following:

- The selection of the criteria is based on the specificity of this study, and as such, provides guidelines for future similar research.
- The development of the FR approach makes it possible to make decisions using incomplete and imprecise information, while uncertainty is included in decision making, and the subjective influence of individual experts is reduced in the decision-making process itself.
- The application of the modified FR SWARA method enables the weights of the criteria to be obtained in proportion to the evaluations of the experts, which simplifies the application of this method.
- A new approach was developed using the CRADIS method, namely the FR approach, which has not been used in research so far.
- The group decision-making process used in this research harmonized the evaluations of the experts, and there was no need to modify the initial FR decision-making matrix, because the upper limits were smaller than the lower limits of the next fuzzy number.

The contribution of this research is reflected in the specificity of this approach, which enables decision making when there is incomplete information and when it is necessary to include uncertainty in the decision-making process. Unlike other similar examples, this research aimed to use a combination of FR numbers to introduce uncertainty into decision making while using imprecise information in decision making. In addition, this paper modified the SWARA method so that it could be used in the FR form. In addition, the combination of SWARA and CRADIS methods in the FR form is presented for the first time in this paper.

However, despite the contributions made by this study, it also has certain limitations. These limitations are firstly reflected in the use of the criteria of this study. Is it possible to take some additional criteria within the main criteria? And is it possible to further divide the main criteria and additional sub-criteria? These possibilities need to be examined in future research, because this study has provided the conceptual foundations that need to be further developed. It is not possible to give all possible answers to possible research questions in one study, but one should focus on certain questions. Then, when conducting this study, one can always ask why five and not more or less experts were used and why six and not more or less contractors were used. This selection depends on the possibility of hiring additional experts as well as finding additional companies that can complete these projects. However, with an increase in the number of experts, the possibility of mismatching their assessments increases, which would complicate the decision itself. The selection of six contractors is due to the fact that the installation of solar panels is not so common in the country of Bosnia and Herzegovina, but new companies appear to be available for this specific construction project. Therefore, in future research, there will be more possible contractors as more and more attention is paid to the installation of solar panels and the production of energy from renewable energy sources. The presented approach based on the FR set should be developed in future research, and new approaches based on the FR set such as neutrosophic, plithogenic, intuitionistic, hesitant, robust, spherical, Pythagorean, and various other approaches should be further developed.

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Conflicts of Interest: The author declares no conflicts of interest.

Appendix A

Table A1. Final values of auxiliary criteria.

C11	C12	C13
([0.06, 0.06][0.07, 0.07][0.08, 0.09])	([0.04, 0.04][0.05, 0.05][0.06, 0.07])	([0.04, 0.04][0.05, 0.05][0.07, 0.07])
C14	C15	C16
([0.04, 0.04][0.05, 0.05][0.06, 0.07])	([0.03, 0.04][0.04, 0.05][0.06, 0.06])	([0.04, 0.04][0.05, 0.05][0.07, 0.07])
C21	C22	C23
([0.05, 0.05][0.06, 0.07][0.07, 0.08])	([0.06, 0.07][0.07, 0.08][0.08, 0.08])	([0.03, 0.04][0.04, 0.05][0.06, 0.06])
C24	C25	C26
([0.04, 0.05][0.05, 0.06][0.07, 0.07])	([0.06, 0.06][0.06, 0.07][0.07, 0.08])	([0.03, 0.04][0.04, 0.05][0.06, 0.06])
C31	C32	C33
([0.03, 0.04][0.04, 0.05][0.06, 0.07])	([0.05, 0.06][0.06, 0.07][0.07, 0.08])	([0.03, 0.03][0.04, 0.05][0.06, 0.06])
C34	C35	C36
([0.04, 0.05][0.05, 0.06][0.07, 0.08])	([0.05, 0.05][0.05, 0.07][0.07, 0.08])	([0.03, 0.03][0.04, 0.04][0.05, 0.06])

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