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Analysis of crowdfunding platforms for microgrid project investors via a q-rung orthopair fuzzy hybrid decision-making approach

Xiaohang Wu[1*], Hasan Dinçer[2] and Serhat Yüksel[2*]

*Correspondence:
xiaohangwu@cqnu.edu.cn;
serhatyuksel@medipol.edu.tr
[1] School of Economics and Management, Chongqing Normal University, Chongqing 401331, China
[2] The School of Business, İstanbul Medipol University, 34817 Beykoz, İstanbul, Turkey

Abstract

Effective crowdfunding platforms positively contribute toward improving microgrid energy management systems. Therefore, a comprehensive analysis is required to understand the key factors responsible for success in crowdfunding systems by considering various criteria. This study evaluates crowdfunding platforms for microgrid project investments. In this context, a novel fuzzy decision-making model that includes two different stages is proposed. First, the selected criteria for the crowdfunding platforms for microgrid project investments are evaluated. Second, alternatives, regarding the microgrid project investments, are ranked. In this process, a multi-stepwise weight assessment ratio analysis (M-SWARA) approach based on q-rung orthopair fuzzy sets (q-ROFSs) is considered. Intuitionistic and Pythagorean fuzzy sets are also used in the calculation process to make a comparative evaluation. Similarly, a sensitivity analysis of the ranking alternatives is also conducted with 12 different q values. All the results are rather similar; thus, the findings are reliable. Another model is also created for this purpose with the help of the decision-making trial and evaluation laboratory (DEMATEL) and the technique for order preference by similarity to ideal solution methodologies to check the performance of the proposed model. It is defined that by considering the q-ROF DEMATEL weights, the ranking results vary for different cases. The proposed model with a M-SWARA is more reliable than the model created via the DEMATEL method. This situation provides information regarding the superiority of the model proposed in this study. It is concluded that security is the most important factor in crowdfunding platforms for smart-grid project investors. Additionally, solar panels and energy storage systems/batteries are the most significant alternatives for microgrid project investors. Necessary measures should be taken to forestall the risk of fraud that may occur on this platform. Therefore, the website to be established must be secure against possible hacking attacks. Another important conclusion of this study is that solar panels should be preliminarily developed to increase the effectiveness of microgrid systems.

Keywords: Financial innovation, Crowdfunding, Microgrid projects, Energy investments, q-rung fuzzy sets

Introduction

Microgrid energy management systems refer to the generation of energy using a common grid by a group (Chen et al. 2022). Every segment in this group simultaneously produces and consumes clean energy (Sahoo and Hota 2021). Moreover, a common battery is available to store excess energy. If the batteries are fully charged, the excess electricity is supplied to the grid. However, if the energy produced in the system does not meet the needs of the institutions in the group, energy is demanded from the grid (Vanashi et al. 2022). In this system, segments that have extra energy can sell this surplus to parties that demand more energy (Norouzi et al. 2021). Hence, one of the greatest advantages of this system is that excess energy can be used efficiently. Additionally, owing to this system, it will be possible to solve the high-cost problem, which is an important obstacle to clean energy investments (Ghazvini et al. 2021). This situation contributes positively toward increasing clean energy investments such that the carbon emission problem can be handled more effectively.

Investments in microgrid energy management systems should be increased to ensure efficient clean energy usage. Therefore, the financing needs of these investments should be satisfied effectively (Atahau et al. 2021). Crowdfunding is also a mechanism that can facilitate the achievement of this goal by bringing project owners and investors together. This system promotes the project through digital platforms so that project owners can reach a wider investor base (Pitchay et al. 2021; Berné-Martínez et al. 2021). Several factors must be considered to design crowdfunding systems appropriately. For example, there should be multichannel communication and rapid feedback on customer questions (Kou et al. 2022; Tang et al. 2021). Furthermore, projects should be introduced adopting user-friendly interfaces. Moreover, security conditions should be satisfied with the help of fraud protection policies and strategies to inhibit misuse by third parties (Peng et al. 2021).

Effective crowdfunding platforms contribute positively to the improvement of microgrid energy management systems. Hence, a comprehensive analysis is required to identify the critical issues for success in crowdfunding systems by considering various criteria. In this study, a novel fuzzy decision-making model is developed to evaluate crowdfunding platforms for microgrid project investments. The analysis process includes two different stages. First, the selected criteria for crowdfunding platforms are weighted. Second, alternatives regarding microgrid project investments are ranked. In this process, the multi-stepwise weight assessment ratio analysis (M-SWARA) method based on q-rung orthopair fuzzy sets (q-ROFSs) is considered. Furthermore, intuitionistic fuzzy sets (IFSs) and Pythagorean fuzzy sets (PFSs) are also used as weight criteria to make a comparative evaluation. Similarly, a sensitivity analysis of the ranking alternatives is also applied with 12 different q values.

Another model is also generated for this purpose with the help of the decision-making trial and evaluation laboratory (DEMATEL) and the technique for order preference by similarity to ideal solution (TOPSIS) methodologies to evaluate the performance of the proposed model. In this context, the weights are also calculated based on the DEMATEL methodology, with the aim of comparing the results with those obtained via the M-SWARA approach. Moreover, with respect to the ranking of the alternatives, another evaluation is performed using the TOPSIS approach to check the coherency of the proposed model. Additionally, different analyses are undertaken to compare the two models. Within this framework, comparative ranking alternatives are computed for different q-values. In addition to this issue, sensitivity analysis is applied to understand whether there is any specific impact of the weights of the criteria on the ranking results. Thus, the weighting results are changed consecutively, and six cases are considered based on q-ROFSs. Based on the consistency of the analysis results, it will be possible to determine which model is more successful.

The main novelty of this study derives from its comprehensive evaluation to identify the key items of an effective crowdfunding system by considering a detailed list of criteria. The analysis results have a leading role for both investors and academics. This study makes an important contribution to the development of clean energy investment projects. Fossil fuels generate carbon emissions that significantly harm the environment. This situation has had a negative impact on the socioeconomic development of countries (Biswas et al. 2021). Clean energy projects should be increased to minimize this problem. However, high costs are a crucial barrier to improving these projects (Qureshi et al. 2020). The analysis results of this study will help in the construction of an effective crowdfunding platform for microgrid energy management systems. In other words, this platform has a positive influence on society while minimizing the carbon emission problem caused by fossil fuels (Azad and Chakraborty 2020).

Additionally, this study has some methodological originalities. For instance, with the help of the SWARA methodology, it is possible to remove some criteria based on expert evaluations (Ronaghi and Ronaghi 2021; Vahabi Nejat et al. 2021; Maghsoodi et al. 2019). In the literature, there are many different studies that consider the SWARA methodology for different purposes (Torkashvand et al. 2021; Yücenur and Ipekçi 2021; Ulutaş et al. 2021; Saraji et al. 2021; Akcan and Taş 2019). However, in this study, an extension of the SWARA method, that is, the multi-SWARA approach, is proposed to determine the relation degrees and weights of the criteria properly. Hence, in contrast to previous studies, this study proposes an original methodology to evaluate crowdfunding platforms for microgrid project investments.

Furthermore, the use of q-ROFSs provides the opportunity to consider a more detailed space (Garg et al. 2021; Paryani et al. 2021; Ali et al. 2021a,b). Therefore, more appropriate results can be obtained by considering these sets (Ali and Sarwar 2021; Asif et al. 2020). Thus, the decision-making problem becomes very complicated. Therefore, there is a need for a new approach for this process. Consequently, in many different studies, multi-criteria decision-making (MCDM) techniques have been considered with fuzzy logic (Meksavang et al. 2019; Liang et al. 2019). Additionally, different fuzzy sets, such as trapezoidal and Gaussian fuzzy sets, have also been generated to obtain more appropriate results (Yang et al. 2021; Berkachy 2021; Azam et al. 2021). Similarly, in this study, q-ROFSs are considered because they focus on a more detailed space in the analysis process (Akram et al. 2021a,b,c). Hence, these sets help to minimize the uncertainty problem in the decision-making process (Habib et al. 2019; Liu et al. 2020).

Furthermore, making a comparative evaluation via the IFSs and PFSs is another novelty of this study. This situation helps to evaluate the results by considering different perspectives. In other words, it provides an opportunity to measure the reliability of the analysis results of the proposed model. Some researchers have proposed a fuzzy decision-making model that considers only one type of fuzzy set (Yüksel et al. 2021; Dinçer et al. 2019; Wang et al. 2019). In these models, the results could not be tested using different fuzzy sets. Moreover, performing a sensitivity analysis with 12 different q-values improves the quality of the proposed model. The main reason is that this analysis helps to check the validity and consistency of the findings (Kirişci et al. 2021; Jafar et al. 2021).

The remainder of this paper is organized as follows: second section presents a literature evaluation of the effectiveness of crowdfunding platforms. The methodological information is presented in third section. The results are provided in fourth section, while the findings are discussed in fifth section.

Literature evaluation of the effectiveness of crowdfunding platforms

Most studies on crowdfunding systems have focused on their benefits. Finding the necessary funds for investment is one of the most important challenges faced by companies. Owing to the inability to manage this problem effectively, many investment projects cannot be implemented (Barber et al. 2021). Because of the crowdfunding system, it is possible to reach many investors in a short period (Shneor et al. 2020). In addition, di Prisco and Strangio (2021) evaluate the relationship between technological development and financial inclusion. They state that funds can be obtained much easily by using crowdfunding platforms so that economic development can be provided more effectively for emerging countries. Furthermore, regional borders are disappearing because of crowdfunding platforms (Dalla Chiesa 2020). In other words, project owners find investors from all over the world. Di Pietro and Masciarelli (2021) examine the impact of the crowdfunding system on the improvement of entrepreneurship. Designing an effective crowdfunding system is helpful for attracting many investors from different regions of the world. Moreover, with the help of this platform, entrepreneurs get the chance to receive early feedback on their intended market and marketing (Wachs and Vedres 2021; Behl and Dutta 2020; Shahab et al. 2021).

Some researchers have also examined the factors necessary to establish an effective crowdfunding platform. In this process, the cost of using the platform should not be too high (Pabst and Mohnen 2021). Otherwise, investors will not prefer this platform because they will lose their cost advantages (Gao et al. 2021). Erjiang et al. (2021) and Xu and Zhang (2021) state that there should be competitive charges for using the platform, transaction, and payment processes. Successful marketing activities play a key role in creating an effective crowdfunding platform (Zhang and Tian 2021; Miglo 2020). Therefore, owners of crowdfunding platforms are required to promote successful marketing activities (Kubo et al. 2021; Kim and Chang 2020). Alegre and Moleskis (2021) study significant financial motivations in crowdfunding systems. As a result of the literature review, they conclude that omni-channel facilities should be considered to attract contributors with creative campaigns in social and personal networks. Troise and Camilleri (2021) and Zheng et al. (2022) also determine that effective marketing strategies play a vital role toward improving crowdfunding platforms.

For crowdfunding platforms to be successful, necessary security measures should be taken. This platform brings both project owners and investors together. In other words, different segments share valuable information on this platform. For example, the owner of a project provides detailed information about the investment issue (Chemla and Tinn 2021; Meoli et al. 2020; Kuo et al. 2022). However, investors also share some of their personal information. Therefore, appropriate precautions should be taken on crowdfunding platforms (Randall et al. 2021; Perbangsa and Udiono 2020). Otherwise, neither investors nor project owners will be willing to use this system. Gregorio et al. (2021) conduct a comparative analysis of crowdfunding platforms. They identify that the necessary security conditions should be satisfied to improve trust for this system. Jiao et al. (2021) highlight the necessary policies for fraud protection and misuse by third parties to improve crowdfunding platforms. Furthermore, customer expectations must be met to increase the platform's effectiveness. Both project owners and investors may face some difficulties while using this system (Di Pietro 2021; Peng et al. 2021). Junge et al. (2021) and Liu et al. (2021) state that there should be multichannel communication and rapid feedback regarding customer questions.

Crowdfunding system have also been examined in many energy investment studies. Bonzanini et al. (2016) state that crowdfunding is a significant financial source for the development of renewable energy projects. Lam and Law (2016), Vasileiadou et al. (2016), and Ari and Koç (2021) focus on ways to improve clean energy investments. They highlight that effective crowdfunding platforms increase the performance of these projects. Nigam et al. (2018) and Candelise (2018) also reach similar conclusions in their studies. Nonetheless, Halden et al. (2021) and Lu et al. (2018) evaluate significant issues to increase solar energy investment projects. They report that finding funds is a very critical condition in this situation. In this context, crowdfunding systems can be very helpful to overcome this problem. Meng et al. (2021) also evaluate crowdfunding alternatives for clean energy investment projects. In this process, new service development pathways are considered.

The literature review shows that an effective crowdfunding platform contributes positively to the improvement of microgrid energy management systems. Nevertheless, various factors must be considered to design crowdfunding systems appropriately. Hence, a comprehensive analysis is required to understand the key factors of success in crowdfunding systems. In this study, we evaluate crowdfunding platforms for microgrid project investments. For this purpose, a comprehensive evaluation is undertaken to identify the key items of an effective crowdfunding system by considering a detailed list of criteria. First, the selected criteria for crowdfunding platforms for microgrid project investments are weighted. In the second stage of the proposed model, the alternatives for microgrid project investments are ranked.

Methodology

This section focuses on q-ROFSs and the proposed decision-making approach. Additionally, the details of the DEMATEL and TOPSIS techniques are detailed.

q-ROFSs

Intuitionistic fuzzy sets (I) aim to obtain more appropriate results for decision-making problems, as shown in Eq. (1). Membership and non-membership degrees are defined as $\mu_I(\vartheta)$ and $n_I(\vartheta)$ (Atanassov 1983).

$$I=\left\{\langle\vartheta,\mu_I(\vartheta),n_I(\vartheta)\rangle|\vartheta\epsilon U\right\} \tag{1}$$

Pythagorean fuzzy sets (P) attempt to identify a new class of nonstandard fuzzy membership grades, as shown in Eq. (2) (Yager 2013; Yager and Abbasov 2013).

$$P=\left\{\langle\vartheta,\mu_P(\vartheta),n_P(\vartheta)\rangle|\vartheta\epsilon U\right\} \tag{2}$$

Equation (3) provides information about the condition.

$$0\leq(\mu_P(\vartheta))^2+(n_P(\vartheta))^2\leq1 \tag{3}$$

The q-ROFSs represent an extension of these two fuzzy numbers (Yager and Alajlan 2017). With the help of these sets, larger spaces can be considered. In this context, the sum of the qth power of the membership and non-membership degrees is considered to be 1 (Yager 2016). Equations (4) and (5) explain these issues:

$$Q=\left\{\langle\vartheta,\mu_Q(\vartheta),n_Q(\vartheta)\rangle|\vartheta\epsilon U\right\} \tag{4}$$

$$0\leq\left(\mu_Q(\vartheta)\right)^q+\left(n_Q(\vartheta)\right)^q\leq1,q\geq1 \tag{5}$$

Equation (6) refers to the degree of indeterminacy.

$$\pi_Q(\vartheta)=\left(\left(\mu_Q(\vartheta)\right)^q+\left(n_Q(\vartheta)\right)^q-\left(\mu_Q(\vartheta)\right)^q\left(n_Q(\vartheta)\right)^q\right)^{1/q} \tag{6}$$

Equations (7)–(11) define the operations (Yager 2016).

$$Q_1=\{\langle\vartheta,Q_1(\mu_{Q_1}(\vartheta),n_{Q_1}(\vartheta))\rangle/\vartheta\epsilon U\}\text{and}Q_2=\{\langle\vartheta,Q_2(\mu_{Q_2}(\vartheta),n_{Q_2}(\vartheta))\rangle/\vartheta\epsilon U\} \tag{7}$$

$$Q_1\oplus Q_2=\left(\left(\mu_{Q_1}^q+\mu_{Q_2}^q-\mu_{Q_1}^q\mu_{Q_2}^q\right)^{1/q},n_{Q_1}n_{Q_2}\right) \tag{8}$$

$$Q_1\otimes Q_2=\left(\mu_{Q_1}\mu_{Q_2},\left(n_{Q_1}^q+n_{Q_2}^q-n_{Q_1}^q n_{Q_2}^q\right)^{1/q}\right) \tag{9}$$

$$\lambda Q=\left(\left(1-\left(1-\mu_Q^q\right)^\lambda\right)^{1/q},\left(n_Q\right)^\lambda\right),\lambda>0 \tag{10}$$

$$Q^\lambda=\left(\left(\mu_Q\right)^\lambda,\left(1-\left(1-n_Q^q\right)^\lambda\right)^{1/q}\right),\lambda>0 \tag{11}$$

Equation (12) is used for defuzzification (Liu et al. 2019).

$$S(\vartheta)=\left(\mu_Q(\vartheta)\right)^q-\left(n_Q(\vartheta)\right)^q \tag{12}$$

Proposed decision-making approach with M-SWARA and q-ROFSs

The SWARA method aims to weight different factors. In this process, decision-makers' hierarchical priorities are considered (Vahabi Nejat et al. 2021). In this study, an extension of the SWARA approach (i.e., the multi-SWARA method) is proposed to properly determine the relation degrees and the weights of the criteria. The computation process of the proposed decision-making approach is detailed as follows:

Step 1: Decision-makers define the dependency degrees with the help of linguistic evaluations.

Step 2: The q-ROF relation matrix is developed as shown in Eq. (13) (Ronaghi and Ronaghi 2021).

$$Q_k = \begin{bmatrix} 0 & Q_{12} & \cdots & \cdots & Q_{1n} \\ Q_{21} & 0 & \cdots & \cdots & Q_{2n} \\ \vdots & \vdots & \ddots & \cdots & \cdots \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ Q_{n1} & Q_{n2} & \cdots & \cdots & 0 \end{bmatrix} \tag{13}$$

where Q is the q-ROF direct relation matrix.$Q_{ij} = \left(\mu_{Q_{ij}}, n_{Q_{ij}}\right)$ and k is the number of decision makers.

Step 3: The q-ROFSs and score functions are calculated using Eqs. (5) and (11).

Step 4: The values of s_j, k_j, q_j, and w_j are calculated as in Eqs. (14)–(16).

$$k_j = \begin{cases} 1 & j = 1 \\ s_j + 1 & j1 \end{cases} \tag{14}$$

$$q_j = \begin{cases} 1 & j = 1 \\ \frac{q_{j-1}}{k_j} & j > 1 \end{cases} \tag{15}$$

$$If s_{j-1} = s_j, q_{j-1} = q_j; If s_j = 0, k_{j-1} = k_j$$

$$w_j = \frac{q_j}{\sum_{k=1}^{n} q_k} \tag{16}$$

The comparative importance rate is denoted as s_j. The importance value of this criterion is denoted by c_j. Additionally, k_j represents the coefficient value of s_j and q_j, while w_j denotes the weights of the criteria under the q-ROFSs. The degrees of significance of the criteria are sorted in descending order (Paryani et al. 2021).

Step 5: The weighting results of w_j are calculated using the stabilization process in the M-SWARA method. The stable values of the relation matrix with the values of w_j are defined by transposing and limiting the matrix to a power of 2t + 1.

Step 6: The q-ROF decision matrix, $X_{ij} = \left[x_{ij}\right]_{m \times n}$, is created using Eq. (17)

$$C_1 C_2 C_3 \ldots C_n$$

$$X_{ij} = \begin{matrix} A_1 \\ A_2 \\ A_3 \\ \vdots \\ A_m \end{matrix} \begin{bmatrix} x_{11} & x_{12} & x_{13} & \ldots & x_{1n} \\ x_{21} & x_{22} & x_{23} & \ldots & x_{2n} \\ x_{31} & x_{32} & x_{33} & \ldots & x_{3n} \\ \vdots & \vdots & \ddots & \ldots & \vdots \\ x_{m1} & x_{m2} & x_{m3} & \ldots & x_{mn} \end{bmatrix} \tag{17}$$

where $X_{ij} = \left(\mu_{x_{ij}}, n_{x_{ij}}\right), i = 1, 2, \ldots m$ and $j = 1, 2, \ldots n$.

Step 7: The q-rung orthopair fuzzy weighted average (q-ROFWA) and q-rung orthopair fuzzy weighted geometric (q-ROFWG) values are computed with Eqs. (18) and (19) (Seker and Aydın 2021).

$$\mathrm{q-ROFWA}(X_1, X_2, \ldots, X_n) = \left(\left(1 - \prod_{i=1}^{n} \left(1 - \mu_{x_i}{}^{q}\right)^{w_i} \right)^{1/q}, \prod_{i=1}^{n} n_{x_i}{}^{w_i} \right) \tag{18}$$

$$\mathrm{q-ROFWG}(X_1, X_2, \ldots, X_n) = \left(\prod_{i=1}^{n} \mu_{x_i}{}^{w_i}, \left(1 - \prod_{i=1}^{n} \left(1 - n_{x_i}{}^{q}\right)^{w_i} \right)^{1/q} \right) \tag{19}$$

where $X_i = \left(\mu_{x_i}, n_{x_i}\right), i = 1, 2, \ldots n, w = (w_1, w_2, \ldots, w_n)^T, \sum_{i=1}^{n} w_i = 1$.

Step 8: The alternatives are ranked.

DEMATEL

Notably, DEMATEL is a decision-making approach that is preferred for weighting different items (Kou et al. 2021). By considering expert evaluations, the relation matrix is constructed as shown in Eq. (20) (Gabus and Fontela 1972).

$$A = \begin{bmatrix} 0 & a_{12} & a_{13} & \cdots & a_{1n} \\ a_{21} & 0 & a_{23} & \cdots & a_{2n} \\ a_{31} & a_{32} & 0 & \cdots & a_{3n} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ a_{n1} & a_{n2} & a_{n3} & \cdots & 0 \end{bmatrix} \tag{20}$$

In the second step, this matrix is normalized using Eqs. (21) and (22) (Fontela and Gabus 1974).

$$B = \frac{A}{max_{1 \le i \le n} \sum_{j=1}^{n} a_{ij}} \tag{21}$$

$$0 \le b_{ij} \le 1 \tag{22}$$

The total relation matrix is built using Eq. (23).

$$\lim_{k \to \infty} \left(B + B^2 + \cdots + B^k\right) = B(I - B)^{-1} \tag{23}$$

The sums of the row (D) and column (E) are computed using Eqs. (24) and (25).

$$D = \left[\sum_{j=1}^{n} e_{ij}\right]_{nx1} \tag{24}$$

$$E = \left[\sum_{i=1}^{n} e_{ij}\right]_{1xn} \tag{25}$$

The sum of these values is used to calculate the weights. Moreover, causal relationship is identified based on their differences. Additionally, Eq. (26) is also considered in constructing the impact–relation map.

$$\alpha = \frac{\sum_{i=1}^{n} \sum_{j=1}^{n} \left[e_{ij}\right]}{N} \tag{26}$$

TOPSIS

Notably, the TOPSIS methodology is used to rank alternatives based on their significance. The vector normalization procedure is implemented to normalize the values by considering Eq. (27) (Yoon and Hwang 1980).

$$r_{ij} = \frac{X_{ij}}{\sqrt{\sum_{i=1}^{m} X_{ij}^2}}. \tag{27}$$

These values are weighted by Eq. (28).

$$v_{ij} = w_{ij} \times r_{ij}. \tag{28}$$

Later, the positive (A^+) and negative (A^-) optimal solutions are determined with Eqs. (29) and (30) (Dinçer et al. 2022).

$$A^+ = \left\{v_{1j}, v_{2j}, \ldots, v_{mj}\right\} = \left\{\max v_{1j} for \forall j \in n\right\}, \tag{29}$$

$$A^- = \left\{v_{1j}, v_{2j}, \ldots, v_{mj}\right\} = \left\{\min v_{1j} for \forall j \in n\right\}. \tag{30}$$

The distances to the best and worst alternatives (D_i^+, D_i^-) are computed using Eqs. (31) and (32).

$$D_i^+ = \sqrt{\sum_{j=1}^{n} \left(v_{ij} - A_j^+\right)^2}, \tag{31}$$

$$D_i^- = \sqrt{\sum_{j=1}^{n} \left(v_{ij} - A_j^-\right)^2}. \tag{32}$$

Equation (33) defines relative closeness to the ideal solution (RC_i).

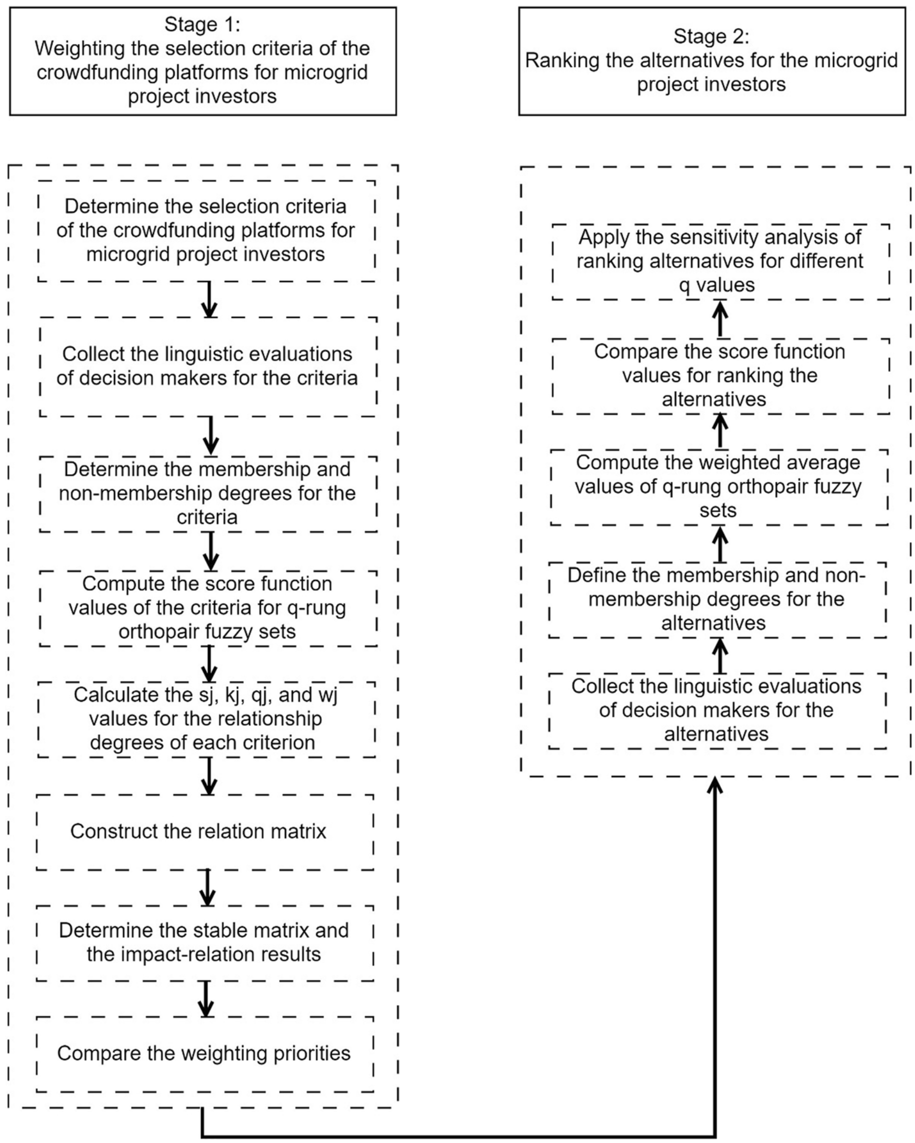

Fig. 1 Algorithm of the proposed decision-making model

$$RC_i = \frac{D_i^-}{D_i^+ + D_i^-}. \quad (33)$$

Analysis results and discussions

The analysis process comprises two different stages. First, the selected criteria regarding crowdfunding platforms for microgrid project investments are weighted. Second, the alternatives for the microgrid project investments are ranked. Figure 1 illustrates these details.

The analysis results will be given based on each stage.

Table 1 Selection criteria of the crowdfunding platforms for smart grid project investors

Criteria	References
Support (CTN 1)	Shneor et al. (2020), Pitchay et al. (2021)
Tools (CTN 2)	Miglo (2020), Berné-Martínez et al. (2021)
Fund (CTN 3)	Dalla Chiesa (2020), Tang et al. (2021), Perbangsa and Udiono (2020)
Security (CTN 4)	Kim and Chang (2020), Yu et al. (2021)
Marketing (CTN 5)	Behl and Dutta (2020), Peng et al. (2021)
Costs (CTN 6)	Meoli et al. (2020), Pitchay et al. (2021)

Table 2 Linguistic scales, membership, and non-membership degrees for criteria and alternatives

Linguistic scales for criteria	Linguistic scales for alternatives	Membership degrees	Non-membership degrees
No influence (n)	Weakest (w)	0.10	0.90
somewhat influence (s)	Poor (p)	0.30	0.70
medium influence (m)	Fair (f)	0.60	0.40
high influence (h)	Good (g)	0.80	0.20
very high influence (vh)	Best (b)	0.90	0.10

Weighting the selection criteria of the crowdfunding platforms for microgrid project investors (Stage 1)

The criteria for crowdfunding platforms for microgrid project investors are selected according to the results in the literature review. The details of these items are listed in Table 1.

To improve the crowdfunding platforms for smart grid project investors, there should be multichannel communication and rapid feedback on customer questions (support-CTN1). Additionally, the setup and introduction of the projects are designed using user-friendly interfaces (tools-CTN2). Third, flexible applications should be generated to withdraw the deposits and several funding offerings with unique rewards and provisions (fund-CTN3). Furthermore, necessary actions should be taken for fraud protection and misuse by third parties (security-CTN4). In addition, effective marketing applications should be considered by omnichannel facilities to attract contributors with creative campaigns in social and personal networks (marketing-CTN5). Finally, there should be competitive charges for using the platform, transaction, and payment processes (costs-CTN6). The values in Table 2 are used in the analysis process.

Table 3 indicates linguistic evaluations.

The average values of membership and non-membership degrees for the criteria are computed, as shown in Table 4.

The score function values of the criteria for the q-ROFSs are listed in Table 5.

The s_j, k_j, q_j, and w_j values are calculated, as shown in Table 6.

The relation matrix is constructed in Table 7.

The stable matrix is calculated as in Table 8.

Table 8 shows that security (CTN4) is the most important factor for the crowdfunding platforms for smart grid project investors. Additionally, support (CTN1), cost (CTN6), and tools (CTN2) also play significant roles in this issue. Nevertheless, fund (CTN3)

Table 3 Linguistic evaluations

	CTN1	CTN2	CTN3	CTN4	CTN5	CTN6
Decision Maker 1						
CTN1		H	M	VH	H	M
CTN2	H		M	H	M	H
CTN3	S	M		M	H	VH
CTN4	H	H	S		M	M
CTN5	M	H	H	M		M
CTN6	M	S	M	H	S	
Decision Maker 2						
CTN1		H	M	VH	H	M
CTN2	H		VH	H	M	H
CTN3	S	M		M	VH	VH
CTN4	H	H	S		S	M
CTN5	M	H	H	M		M
CTN6	VH	M	M	H	S	
Decision Maker 3						
CTN1		M	M	VH	H	M
CTN2	H		M	H	M	H
CTN3	M	M		M	VH	VH
CTN4	H	H	S		S	M
CTN5	M	H	H	M		H
CTN6	H	M	M	H	M	

Table 4 Average values of membership and non-membership degrees for the criteria

	CTN1		CTN2		CTN3		CTN4		CTN5		CTN6	
	μ	v	μ	v	μ	v	μ	v	μ	v	μ	v
CTN1			0.73	0.27	0.60	0.40	0.90	0.10	0.80	0.20	0.60	0.40
CTN2	0.80	0.20			0.70	0.30	0.80	0.20	0.60	0.40	0.80	0.20
CTN3	0.40	0.60	0.60	0.40			0.60	0.40	0.87	0.13	0.90	0.10
CTN4	0.80	0.20	0.80	0.20	0.30	0.70			0.40	0.60	0.60	0.40
CTN5	0.60	0.40	0.80	0.20	0.80	0.20	0.60	0.40			0.67	0.33
CTN6	0.77	0.23	0.50	0.50	0.60	0.40	0.80	0.20	0.40	0.60		

Table 5 Score function values of the criteria for q-ROFSs

	CTN1	CTN2	CTN3	CTN4	CTN5	CTN6
CTN1	0.000	0.375	0.152	0.728	0.504	0.152
CTN2	0.504	0.000	0.316	0.504	0.152	0.504
CTN3	0.000	0.152	0.000	0.152	0.649	0.728
CTN4	0.504	0.504	0.000	0.000	0.000	0.152
CTN5	0.152	0.504	0.504	0.152	0.000	0.259
CTN6	0.438	0.000	0.152	0.504	0.000	0.000

Table 6 S_j, k_j, q_j, and w_j values for the relationship degrees of each criterion

CTN1	S_j	k_j	q_j	w_j	CTN2	S_j	k_j	q_j	w_j
CTN5		1.000	1.000	0.335	CTN4		1.000	1.000	0.366
CTN2	0.504	1.504	0.665	0.223	CTN6	0.504	1.504	0.665	0.243
CTN3	0.375	1.375	0.483	0.162	CTN3	0.504	1.504	0.442	0.162
CTN4	0.152	1.152	0.420	0.140	CTN5	0.316	1.316	0.336	0.123
CTN6	0.152	1.152	0.420	0.140	CTN1	0.152	1.152	0.292	0.107
CTN3	S_j	k_j	q_j	w_j	CTN4	S_j	k_j	q_j	w_j
CTN6		1.000	1.000	0.321	CTN2		1.000	1.000	0.229
CTN1	0.649	1.649	0.607	0.195	CTN1	0.504	1.504	1.000	0.229
CTN2	0.152	1.152	0.527	0.169	CTN3	0.152	1.152	0.868	0.198
CTN4	0.152	1.152	0.527	0.169	CTN5	0.000	1.152	0.754	0.172
CTN5	0.000	1.152	0.457	0.147	CTN6	0.000	1.152	0.754	0.172
CTN5	S_j	k_j	q_j	w_j	CTN6	S_j	k_j	q_j	w_j
CTN1		1.000	1.000	0.240	CTN4		1.000	1.000	0.299
CTN2	0.504	1.504	1.000	0.240	CTN2	0.438	1.438	0.695	0.208
CTN6	0.259	1.259	0.794	0.190	CTN3	0.152	1.152	0.604	0.180
CTN3	0.152	1.152	0.689	0.165	CTN5	0.000	1.152	0.524	0.157
CTN4	0.152	1.152	0.689	0.165	CTN1	0.000	1.152	0.524	0.157

Table 7 Relation matrix with the values of wj

	CTN1	CTN2	CTN3	CTN4	CTN5	CTN6
CTN1		0.162	0.140	0.335	0.223	0.140
CTN2	0.366		0.123	0.243	0.107	0.162
CTN3	0.147	0.169		0.169	0.195	0.321
CTN4	0.229	0.229	0.172		0.172	0.198
CTN5	0.165	0.240	0.240	0.165		0.190
CTN6	0.208	0.157	0.180	0.299	0.157	

Table 8 Stable matrix

	CTN1	CTN2	CTN3	CTN4	CTN5	CTN6
CTN1	0.184	0.184	0.184	0.184	0.184	0.184
CTN2	0.161	0.161	0.161	0.161	0.161	0.161
CTN3	0.145	0.145	0.145	0.145	0.145	0.145
CTN4	0.199	0.199	0.199	0.199	0.199	0.199
CTN5	0.146	0.146	0.146	0.146	0.146	0.146
CTN6	0.166	0.166	0.166	0.166	0.166	0.166

and marketing (CTN5) have lower weights. The causal relationship between the items is shown in Fig. 2.

Support (CTN1) and security (CTN4) are the most influential items. In the next step, a comparative evaluation is performed by considering IFSs and PFSs. Additionally, the weights are calculated based on the DEMATEL approach to compare the results with those of the M-SWARA methodology. Table 9 presents the results of the comparative analysis.

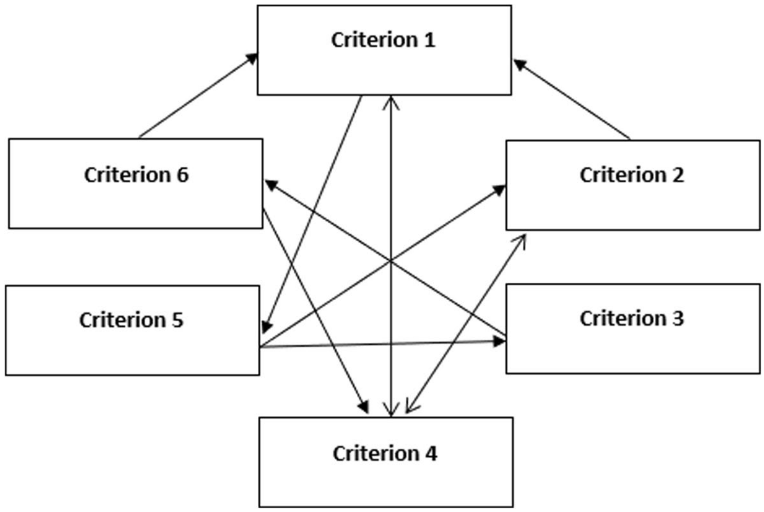

Fig. 2 Impact–relation map for the criteria

Table 9 Comparative weighting priorities for the criteria

	M-SWARA			DEMATEL		
	IFSs	PFSs	q-ROFSs	IFSs	PFSs	q-ROFSs
CTN1	2	2	2	2	2	2
CTN2	4	4	4	3	3	3
CTN3	6	6	6	6	6	6
CTN4	1	1	1	1	1	1
CTN5	5	5	5	4	4	4
CTN6	3	3	3	5	5	5

Table 9 shows that the weighting results of the three different fuzzy sets based on the M-SWARA approach are the same. However, the weighting priorities are also similar for the three different fuzzy sets with respect to the analysis made via the DEMATEL method. Additionally, the best and worst criteria are the same in both the M-SWARA and DEMATEL methodologies. This indicates that the findings of the proposed model are coherent.

Ranking the alternatives for the microgrid project investors (Stage 2)

The types/alternatives of microgrids are defined as combined heat and power (ALV1), wind turbines (ALV2), solar panels (ALV3), generators (ALV4), and energy storage systems/batteries (ALV5). The linguistic evaluations are presented in Table 10.

The average values of the membership and non-membership degrees for the alternatives are listed in Table 11.

The weighted average values are shown in Table 12.

In addition to the analysis with weighted average values, another evaluation is performed via the TOPSIS analysis to verify the coherency of the proposed model. The comparative ranking results are given using the score function values of the weighted average values and the relative closeness to the ideal solutions in Table 13.

Table 10 Linguistic evaluations for the alternatives

	CTN1	CTN2	CTN3	CTN4	CTN5	CTN6
Decision Maker 1						
ALV1	G	F	F	F	B	F
ALV2	F	G	G	F	F	G
ALV3	B	B	F	G	F	P
ALV4	G	P	B	G	G	P
ALV5	F	F	G	B	B	G
Decision Maker 2						
ALV1	B	P	F	G	F	G
ALV2	F	F	G	F	F	G
ALV3	B	B	F	G	F	F
ALV4	G	P	B	G	G	F
ALV5	B	F	B	G	F	G
Decision Maker 3						
ALV1	F	F	F	F	G	F
ALV2	G	F	F	F	F	G
ALV3	G	G	F	G	F	F
ALV4	G	F	G	G	G	F
ALV5	F	F	G	F	F	F

Table 11 Average values of the membership and non-membership degrees for the alternatives

	CTN1		CTN2		CTN3		CTN4		CTN5		CTN6	
	μ	v	μ	v	μ	v	μ	v	μ	v	μ	v
ALV1	0.77	0.23	0.50	0.50	0.60	0.40	0.67	0.33	0.77	0.23	0.67	0.33
ALV2	0.67	0.33	0.67	0.33	0.73	0.27	0.60	0.40	0.60	0.40	0.80	0.20
ALV3	0.87	0.13	0.87	0.13	0.60	0.40	0.80	0.20	0.60	0.40	0.50	0.50
ALV4	0.80	0.20	0.40	0.60	0.87	0.13	0.80	0.20	0.80	0.20	0.50	0.50
ALV5	0.70	0.30	0.60	0.40	0.83	0.17	0.77	0.23	0.70	0.30	0.73	0.27

Table 12 Weighted average values of q-ROFSs

	q-ROFWA		q-ROFWG	
	μ	v	μ	v
ALV1	0.682	0.325	0.657	0.363
ALV2	0.689	0.316	0.672	0.340
ALV3	0.766	0.248	0.700	0.350
ALV4	0.756	0.262	0.670	0.399
ALV5	0.735	0.269	0.719	0.295

Table 13 shows that solar panels (ALV3) are the most important items for q-ROFWA. However, energy storage systems/batteries (ALV5) play the most crucial role in the q-ROFWG. It is defined that the rankings of the three different fuzzy sets are similar regarding the analysis made by the weighted average values. Moreover, the ranking results using the TOPSIS technique are also the same for different fuzzy sets. Furthermore, the rankings of the weighted average values and the TOPSIS technique

Table 13 Comparative ranking results for the alternatives

	IFWA	IFWG	PFWA	PFWG	q-ROFWA	q-ROFWG	IF-TOPSIS	PF-TOPSIS	q-ROF TOPSIS
ALV1	5	5	5	5	5	5	5	5	5
ALV2	4	4	4	3	4	3	3	3	3
ALV3	1	2	1	2	1	2	1	1	1
ALV4	2	3	2	4	2	4	4	4	4
ALV5	3	1	3	1	3	1	2	2	2

Table 14 Ranking alternatives with different q-values

Q values	Methods	Alternatives				
		ALV1	ALV2	ALV3	ALV4	ALV5
Q:1	WA	5	4	1	2	3
	WG	5	4	2	3	1
	TOPSIS	5	3	1	4	2
Q:2	WA	5	4	1	2	3
	WG	5	3	2	4	1
	TOPSIS	5	3	1	4	2
Q:3	WA	5	4	1	2	3
	WG	5	3	2	4	1
	TOPSIS	5	3	1	4	2
Q:4	WA	5	4	1	2	3
	WG	5	3	2	4	1
	TOPSIS	5	3	1	4	2
Q:5	WA	5	4	1	2	3
	WG	5	3	2	4	1
	TOPSIS	5	4	1	3	2
Q:6	WA	5	4	1	2	3
	WG	5	3	2	4	1
	TOPSIS	5	4	1	3	2
Q:7	WA	5	4	1	2	3
	WG	5	3	2	4	1
	TOPSIS	5	4	1	3	2
Q:8	WA	5	4	1	2	3
	WG	5	3	2	4	1
	TOPSIS	5	4	1	2	3
Q:9	WA	5	4	1	2	3
	WG	5	3	2	4	1
	TOPSIS	5	4	1	2	3
Q:10	WA	5	4	1	2	3
	WG	5	3	2	4	1
	TOPSIS	5	4	1	2	3
Q:15	WA	5	4	1	2	3
	WG	5	3	2	4	1
	TOPSIS	5	4	1	2	3
Q:20	WA	5	4	1	2	3
	WG	5	3	2	4	1
	TOPSIS	5	4	1	2	3

Table 15 Sensitivity analysis results based on q-ROF M-SWARA

Cases	Methods	Alternatives				
		ALV1	ALV2	ALV3	ALV4	ALV5
Case 1	WA	5	4	1	2	3
	WG	5	3	2	4	1
	TOPSIS	5	3	1	4	2
Case 2	WA	5	4	1	2	3
	WG	5	3	2	4	1
	TOPSIS	5	3	1	4	2
Case 3	WA	5	4	1	2	3
	WG	5	3	2	4	1
	TOPSIS	5	3	1	4	2
Case 4	WA	5	4	1	2	3
	WG	5	3	2	4	1
	TOPSIS	5	3	1	4	2
Case 5	WA	5	4	1	2	3
	WG	5	3	2	4	1
	TOPSIS	5	3	1	4	2
Case 6	WA	5	4	1	2	3
	WG	5	3	2	4	1
	TOPSIS	5	3	1	4	2

are quite similar. Additionally, to check the reliability of the proposed model, comparative ranking alternatives are also computed for different q-values, as shown in Table 14.

Table 14 presents the comparative results of the ranking alternatives for the 12 different q-values. The results show that the analysis results of the q-ROFWA and q-ROFWG operators are rather similar for different q-values. Thus, it is also concluded that the ranking results of the TOPSIS method are similar for all the different q-values. This situation demonstrates that the proposed hybrid decision-making approach based on q-ROFSs in this study is coherent, and the model can be duly extended for further fuzzy-based decision-making model studies.

Additionally, a sensitivity analysis is applied to determine whether there is any specific impact of the weights of the criteria on the ranking results. For this purpose, the weighting results are changed consecutively, and six cases are considered based on the q-ROF M-SWARA and DEMATEL approaches. The results are presented in Tables 15 and 16, respectively.

Table 15 indicates that by considering the weights calculated using the M-SWARA method, alternative rankings are the same for all different cases regarding the WA, WG, and TOPSIS methodologies. This indicates that the proposed model is consistent with the M- SWARA methodology based on q-ROFSs. Table 16 provides information on the sensitivity analysis of the ranking results by considering the weights of the DEMATEL approach.

Table 16 demonstrates that, by considering the weights of the q-ROF DEMATEL method, the ranking results vary for different cases. The proposed model with the M-SWARA approach in this study is more reliable than the model created via the

Table 16 Sensitivity analysis results based on q-ROF DEMATEL

Cases	Methods	Alternatives				
		ALV1	ALV2	ALV3	ALV4	ALV5
Case 1	WA	5	4	1	2	3
	WG	5	4	2	3	1
	TOPSIS	5	4	1	3	2
Case 2	WA	4	5	2	1	3
	WG	5	4	1	3	2
	TOPSIS	4	3	1	5	2
Case 3	WA	5	4	1	2	3
	WG	5	4	2	3	1
	TOPSIS	5	4	1	3	2
Case 4	WA	5	4	1	2	3
	WG	5	3	2	4	1
	TOPSIS	5	3	1	4	2
Case 5	WA	5	4	1	2	3
	WG	5	4	2	3	1
	TOPSIS	5	4	1	3	2
Case 6	WA	4	5	2	1	3
	WG	5	4	1	3	2
	TOPSIS	4	3	2	5	1

DEMATEL method. This situation provides information about the superiority of the model proposed in this study.

To develop a crowdfunding platform, it is important to ensure the security of the system. In this context, necessary measures should be taken against the risk of fraud that may occur on this platform. Therefore, the website to be established must be secure against possible hacking attacks. To ensure security, both project owners and investors will prefer to use this platform. This will help to increase the effectiveness of the crowdfunding system. Meoli et al. (2020), Wu et al. (2022), and Asfarian et al. (2020) determined ways to increase the effectiveness of the crowdfunding system and discussed that appropriate policies should be implemented for fraud protection and misuse by third parties. Another important conclusion of this study is that solar panels should be preliminarily developed to increase the effectiveness of microgrid systems. The efficiency of solar energy projects has increased, particularly with the help of recent technological developments. This situation has a positive impact on decreasing the costs of solar energy projects. Asrami et al. (2021), Li et al. (2022), Lundheim et al. (2021), and Derakhshandeh et al. (2021) also reach this conclusion in their evaluations.

Conclusions

This study aims to evaluate crowdfunding platforms for microgrid project investments. The proposed model includes two different stages. First, the selected criteria for crowdfunding platforms for microgrid project investments are weighted. In the second stage, the alternatives for the microgrid project investments are ranked. In this process, the M-SWARA method based on q-ROFSs is considered. The IFSs and PFSs are also used as weight criteria to make a comparative evaluation. Similarly, a sensitivity analysis of the ranking alternatives is also applied with 12 different q-values. Because all the results are quite similar, the findings of the proposed model are coherent. Another model is created for this purpose with the help of the DEMATEL and TOPSIS methodologies to appraise the performance of the proposed model. Furthermore, to check the reliability of the proposed model, comparative ranking alternatives are computed for different q-values. It is concluded that by considering the q-ROF DEMATEL weights, the ranking results vary for different cases. The proposed model with the M-SWARA approach is more reliable than the model created via the DEMATEL method. This situation provides information regarding the superiority of the model proposed in this study.

It is concluded that security is the most important factor in the crowdfunding platforms for smart-grid project investors. Furthermore, support, cost, and tools also play a significant role in this issue. Solar panels and energy storage systems/batteries are the most significant alternatives for microgrid project investors. The main limitation of this study is that only crowdfunding systems are considered among the financial alternatives to microgrid energy management systems. However, some other financial sources, such as equity and debt financing, can also be used to improve these systems. In future studies, a new examination can be conducted to determine the best financial sources for microgrid energy management systems. Other MCDM models, such as AHP and VIKOR, can also be considered in the evaluation process.

Abbreviations
CTN: Criterion; DEMATEL: Decision making trial and evaluation laboratory; SWARA: The Stepwise Weight Assessment Ratio Analysis; TOPSIS: Technique for Order Preference by Similarity to Ideal Solution.

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Author contributions
XW participated in the design of the study and performed the statistical analysis and conceived of the study and participated in its design and coordination and helped to draft the manuscript. HD participated in the design of the study and performed the statistical analysis. SY conceived of the study and participated in its design and coordination and helped to draft the manuscript. All authors read and approved the final manuscript.

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References
Akcan S, Taş MA (2019) Green supplier evaluation with SWARA-TOPSIS integrated method to reduce ecological risk factors. Environ Monit Assess 191(12):1–22
Akram M, Shahzadi G (2021) A hybrid decision-making model under q-rung orthopair fuzzy Yager aggregation operators. Granul Comput 6(4):763–777
Akram M, Shahzadi G, Peng X (2021b) Extension of Einstein geometric operators to multi-attribute decision making under q-rung orthopair fuzzy information. Granul Comput 6(4):779–795
Akram M, Shahzadi G, Butt MA, Karaaslan F (2021c) A hybrid decision making method based on q-rung orthopair fuzzy soft information. J Intell Fuzzy Syst 40(5):9815–9830

Akram M, Shahzadi G, Alcantud JCR (2021a) Multi-attribute decision-making with q-rung picture fuzzy information. Granul Comput 1–19
Alegre I, Moleskis M (2021) Beyond financial motivations in crowdfunding: A systematic literature review of donations and rewards. Voluntas Int J Volunt Nonprofit Org 32(2):276–287
Ali G, Alolaiyan H, Pamučar D, Asif M, Lateef N (2021b) A novel MADM framework under q-rung orthopair fuzzy bipolar soft sets. Mathematics 9(17):2163
Ali G, Sarwar M (2021) Novel technique for group decision-making under fuzzy parameterized q-rung orthopair fuzzy soft expert framework. Math Prob Eng 2021
Ali G, Afzal M, Asif M, Shazad A (2021a) Attribute reduction approaches under interval-valued q-rung orthopair fuzzy soft framework. Appl Intell 1–26
Ari I, Koc M (2021) Philanthropic-crowdfunding-partnership: a proof-of-concept study for sustainable financing in low-carbon energy transitions. Energy 222:119925
Asfarian A, Putra RP, Panatagama AP, Nurhadryani Y, Ramadhan DA (2020) E-initiative for food security: design of mobile crowdfunding platform to reduce food insecurity in Indonesia. In: 2020 8th international conference on information and communication technology (ICoICT). IEEE, pp 1–5.
Asif M, Akram M, Ali G (2020) Pythagorean fuzzy matroids with application. Symmetry 12(3):423
Asrami RF, Sohani A, Saedpanah E, Sayyaadi H (2021) Towards achieving the best solution to utilize photovoltaic solar panels for residential buildings in urban areas. Sustain Cities Soc 71:102968
Atahau ADR, Sakti IM, Huruta AD, Kim MS (2021) Gender and renewable energy integration: the mediating role of green-microfinance. J Clean Prod 318:128536
Atanassov KT (1983) Intuitionistic fuzzy sets VII ITKR's Session. Sofia June 1:983
Azad R, Chakraborty S (2020) Green growth and the right to energy in India. Energy Policy 141:111456
Azam MH, Hasan MH, Hassan S, Abdulkadir SJ (2021) A Novel approach to generate type-1 fuzzy triangular and trapezoidal membership functions to improve the classification accuracy. Symmetry 13(10):1932
Barber BM, Morse A, Yasuda A (2021) Impact investing. J Financ Econ 139(1):162–185
Behl A, Dutta P (2020) Engaging donors on crowdfunding platform in Disaster Relief Operations (DRO) using gamification: a Civic Voluntary Model (CVM) approach. Int J Inf Manag 54:102140
Berkachy R (2021) Fundamental concepts on fuzzy sets. In: The signed distance measure in fuzzy statistical analysis. Springer, Cham, pp 13–33
Berné-Martínez JM, Ortigosa-Blanch A, Planells-Artigot E (2021) A semantic analysis of crowdfunding in the digital press. Technol Forecast Soc Change 173:121175
Biswas A, Swain S, Maiti DK (2021) Eco-friendly cost-effective energy-storage device for the benefit of society. In: Nano tools and devices for enhanced renewable energy. Elsevier, pp 567–583
Bonzanini D, Giudici G, Patrucco A (2016) The crowdfunding of renewable energy projects. In: Handbook of environmental and sustainable finance. Academic Press, pp 429–444
Candelise C. (2018) The application of crowdfunding to the energy sector. In: Sustainable development: concepts, methodologies, tools, and applications. IGI Global, pp 1680–1701
Chemla G, Tinn K (2021) How wise are crowds on crowdfunding platforms? Palgrave Handb Technol Finance 397–406
Chen T, Cao Y, Qing X, Zhang J, Sun Y, Amaratunga GA (2022) Multi-energy microgrid robust energy management with a novel decision-making strategy. Energy 239:121840
Dalla Chiesa C (2020) From digitalisation to crowdfunding platforms: fomenting the cultural commons. In: Cultural commons and urban dynamics. Springer, Cham, pp 173–186
Derakhshandeh JF, AlLuqman R, Mohammad S, AlHussain H, AlHendi G, AlEid D, Ahmad Z (2021) A comprehensive review of automatic cleaning systems of solar panels. Sustain Energy Technol Assess 47:101518
Dinçer H, Yüksel S, Martinez L (2019) Balanced scorecard-based Analysis about European Energy Investment Policies: a hybrid hesitant fuzzy decision-making approach with Quality Function Deployment. Expert Syst Appl 115:152–171
Dinçer H, Yüksel S, Martínez L (2022) Collaboration enhanced hybrid fuzzy decision-making approach to analyze the renewable energy investment projects. Energy Rep 8:377–389
Erjiang E, Yu M, Peng G (2021) Intermediation in reward-based crowdfunding: a cash deposit mechanism to reduce moral hazard. Electron Commer Res 1–22
Fontela E, Gabus A (1974) DEMATEL, innovative methods, rep. no. 2, structural analysis of the world problematique (methods), Battelle Institute, Geneva Research Center, Geneva
Gabus A, Fontela E (1972) World problems, an invitation to further thought within the framework of DEMATEL. Battelle Geneva Research Center, Geneva, Switzerland, pp 1–8
Gao Q, Guo X, Yang F, Yu Y (2021) Commitment or not? Creator's quality strategies with uncertain market in reward-based crowdfunding. Int J Prod Res 1–25
Garg H, Ali Z, Mahmood T, Aljahdali S, Shah H (2021) New logarithmic operational laws-based complex q-rung orthopair fuzzy aggregation operators and their application in decision-making process. Complexity 2021
Ghazvini A, Sedighizadeh M, Olamaei J (2021) Semidefinite programing as a tool for economic-environmental operation of a microgrid including compressed air energy storage and electric vehicle. J Energy Storage 43:103215
Gregorio VF, Papaoikonomou E, Terceño A (2021) Unpeel the layers of trust! A comparative analysis of crowdfunding platforms and what they do to generate trust. Bus Horiz
Habib A, Akram M, Farooq A (2019) q-Rung orthopair fuzzy competition graphs with application in the soil ecosystem. Mathematics 7(1):91
Halden U, Cali U, Dynge MF, Stekli J, Bai L (2021) DLT-based equity crowdfunding on the techno-economic feasibility of solar energy investments. Sol Energy 227:137–150
Jafar MN, Saeed M, Saqlain M, Yang MS (2021) Trigonometric similarity measures for neutrosophic hypersoft sets with application to renewable energy source selection. IEEE Access
Jiao H, Tang W, Liu T, Wang X, Ma L (2021) How do IT affordances support behavioral intention in charitable crowdfunding? The mediating effects of donor perceptions and motivations. Kybernetes

Junge LB, Laursen IC, Nielsen KR (2021) Choosing crowdfunding: why do entrepreneurs choose to engage in crowdfunding? Technovation 111:102385
Kim H, Chang B (2020) A study on the effects of crowdfunding values on the intention to visit local festivals: focusing on mediating effects of perceived risk and e-WOM. Sustainability 12(8):3264
Kirişci M, Demir İ, Şimşek N, Topaç N, Bardak M (2021) The novel VIKOR methods for generalized Pythagorean fuzzy soft sets and its application to children of early childhood in COVID-19 quarantine. Neural Comput Appl 1–27
Kou G, Olgu Akdeniz Ö, Dinçer H, Yüksel S (2021) Fintech investments in European banks: a hybrid IT2 fuzzy multidimensional decision-making approach. Financ Innov 7(1):1–28
Kou G, Yüksel S, Dinçer H (2022) Inventive problem-solving map of innovative carbon emission strategies for solar energy-based transportation investment projects. Appl Energy 311:118680
Kubo T, Veríssimo D, Uryu S, Mieno T, MacMillan D (2021) What determines the success and failure of environmental crowdfunding? Ambio 1–11
Kuo YF, Lin CS, Liu LT (2022) The effects of framing messages and cause-related marketing on backing intentions in reward-based crowdfunding. J Retail Consumer Serv 64:102799
Lam PT, Law AO (2016) Crowdfunding for renewable and sustainable energy projects: an exploratory case study approach. Renew Sustain Energy Rev 60:11–20
Li M, Virguez E, Shan R, Tian J, Gao S, Patiño-Echeverri D (2022) High-resolution data shows China's wind and solar energy resources are enough to support a 2050 decarbonized electricity system. Appl Energy 306:117996
Liang D, Zhang Y, Xu Z, Jamaldeen A (2019) Pythagorean fuzzy VIKOR approaches based on TODIM for evaluating internet banking website quality of Ghanaian banking industry. Appl Soft Comput 78:583–594
Liu Z, Li L, Li J (2019) q-Rung orthopair uncertain linguistic partitioned Bonferroni mean operators and its application to multiple attribute decision-making method. Int J Intell Syst 34(10):2490–2520
Liu P, Shahzadi G, Akram M (2020) Specific types of q-rung picture fuzzy Yager aggregation operators for decision-making. Int J Comput Intell Syst 13(1):1072–1091
Liu Q, Liu X, Balachander S (2021) Crowdfunding project design: optimal product menu and funding target. Prod Oper Manag
Lu Y, Chang R, Lim S (2018) Crowdfunding for solar photovoltaics development: a review and forecast. Renew Sustain Energy Rev 93:439–450
Lundheim SH, Vesely S, Nayum A, Klöckner CA (2021) From vague interest to strong intentions to install solar panels on private homes in the North–An analysis of psychological drivers. Renew Energy 165:455–463
Maghsoodi AI, Maghsoodi AI, Poursoltan P, Antucheviciene J, Turskis Z (2019) Dam construction material selection by implementing the integrated SWARA—CODAS approach with target-based attributes. Arch Civ Mech Eng 19(4):1194–1210
Meksavang P, Shi H, Lin SM, Liu HC (2019) An extended picture fuzzy VIKOR approach for sustainable supplier management and its application in the beef industry. Symmetry 11(4):468
Meng Y, Wu H, Zhao W, Chen W, Dinçer H, Yüksel S (2021) A hybrid heterogeneous Pythagorean fuzzy group decision modelling for crowdfunding development process pathways of fintech-based clean energy investment projects. Financ Innov 7(1):1–34
Meoli M, Rossi A, Vismara S (2020) Financial literacy and security-based crowdfunding. Corp Govern Int Rev
Miglo A (2020) Crowdfunding in a competitive environment. J Risk Financ Manag 13(3):39
Nigam N, Mbarek S, Benetti C (2018) Crowdfunding to finance eco-innovation: case studies from leading renewable energy platforms. J Innov Econ Manag 2:195–219
Norouzi M, Aghaei J, Pirouzi S, Niknam T, Fotuhi-Firuzabad M (2021) flexibility pricing of integrated unit of electric spring and EVs parking in microgrids. Energy 239:122080
Pabst S, Mohnen A (2021) On founders and dictators: does it pay to pay for signals in crowdfunding? J Bus Ventur Insights 15:e00247
Paryani S, Neshat A, Pradhan B (2021) Improvement of landslide spatial modeling using machine learning methods and two Harris hawks and bat algorithms. Egypt J Remote Sens Space Sci
Peng L, Cui G, Bao Z, Liu S (2021) Speaking the same language: the power of words in crowdfunding success and failure. Mark Lett 1–13
Perbangsa AS, Udiono T (2020) The model of web-based crowdfunding platform. In: 2020 international conference on information management and technology (ICIMTech). IEEE, pp 957–961
Di Pietro F, Masciarelli F (2021) The effect of local religiosity on financing cross-regional entrepreneurial projects via crowdfunding (Local religiosity and crowdfinancing). J Bus Ethics 1–15
Di Pietro F (2021) The rationale for listing on equity crowdfunding: actual and expected benefits for companies. J Ind Bus Econ 1–23
Pitchay AA, Eliz NMA, Ganesan Y, Mydin AA, Ratnasari RT, Thaker MAMT (2021) Self-determination theory and individuals' intention to participate in donation crowdfunding. Int J Islam Middle East Finance Manag
di Prisco D, Strangio D (2021) Technology and financial inclusion: a case study to evaluate potential and limitations of Blockchain in emerging countries. Technol Anal Strateg Manag 1–14
Qureshi KN, Hussain R, Jeon G (2020) A distributed software defined networking model to improve the scalability and quality of services for flexible green energy internet for smart grid systems. Comput Electr Eng 84:106634
Randall N, Šabanović S, Milojević S, Gupta A (2021) Top of the class: mining product characteristics associated with crowdfunding success and failure of home robots. Int J Soc Robot 1–15
Ronaghi M, Ronaghi MH (2021) Investigating the impact of economic, political, and social factors on augmented reality technology acceptance in agriculture (livestock farming) sector in a developing country. Technol Soc 67:101739
Sahoo A, Hota PK (2021) Impact of energy storage system and distributed energy resources on bidding strategy of micro-grid in deregulated environment. J Energy Storage 43:103230
Saraji MK, Mardani A, Köppen M, Mishra AR, Rani P (2021) An extended hesitant fuzzy set using SWARA-MULTIMOORA approach to adapt online education for the control of the pandemic spread of COVID-19 in higher education institutions. Artif Intell Rev 1–26

Seker S, Aydin N (2021) Assessment of hydrogen production methods via integrated MCDM approach under uncertainty. Int J Hydrog Energy
Shahab Y, Riaz Y, Ntim CG, Ye Z, Zhang Q, Feng R (2021) Online feedback and crowdfunding finance in China. Int J Finance Econ 26(3):4634–4652
Shneor R, Zhao L, Flåten BT (2020) Introduction: from fundamentals to advances in crowdfunding research and practice. In: Advances in crowdfunding. Palgrave Macmillan, Cham, pp 1–18
Tang X, Lu H, Huang W, Liu S (2021) Investment decisions and pricing strategies of crowdfunding players: in a two-sided crowdfunding market. Electron Commerce Res 1–32
Torkashvand M, Neshat A, Javadi S, Yousefi H (2021) DRASTIC framework improvement using stepwise weight assessment ratio analysis (SWARA) and combination of genetic algorithm and entropy. Environ Sci Pollut Res 28(34):46704–46724
Troise C, Camilleri MA (2021) The use of digital media for marketing, CSR communication and stakeholder engagement. In: Strategic corporate communication in the digital age. Emerald Publishing Limited
Ulutaş A, Meidute-Kavaliauskiene I, Topal A, Demir E (2021) Assessment of collaboration-based and non-collaboration-based logistics risks with plithogenic SWARA method. Logistics 5(4):82
Vahabi Nejat S, Avakh Darestani S, Omidvari M, Adibi MA (2021) Evaluation of green lean production in textile industry: a hybrid fuzzy decision-making framework. Environ Sci Pollut Res 1–22
Vanashi HK, Mohammadi FD, Verma V, Solanki J, Solanki SK (2022) Hierarchical multi-agent based frequency and voltage control for a microgrid power system. Int J Electr Power Energy Syst 135:107535
Vasileiadou E, Huijben JCCM, Raven RPJM (2016) Three is a crowd? Exploring the potential of crowdfunding for renewable energy in the Netherlands. J Clean Prod 128:142–155
Wachs J, Vedres B (2021) Does crowdfunding really foster innovation? Evidence from the board game industry. Technol Forecast Soc Change 168:120747
Wang S, Liu Q, Yuksel S, Dincer H (2019) Hesitant linguistic term sets-based hybrid analysis for renewable energy investments. IEEE Access 7:114223–114235
Wu Y, Zhang X, Xiao Q (2022) Appeal to the head and heart: The persuasive effects of medical crowdfunding charitable appeals on willingness to donate. Inf Process Manag 59(1):102792
Xu S, Zhang Z (2021) Choosing a crowdfunding model considering strategic customer behaviour. Total Qual Manag Bus Excell 1–22
Yager RR (2016) Generalized orthopair fuzzy sets. IEEE Trans Fuzzy Syst 25(5):1222–1230
Yager RR, Abbasov AM (2013) Pythagorean membership grades, complex numbers, and decision making. Int J Intell Syst 28(5):436–452
Yager RR, Alajlan N (2017) Approximate reasoning with generalized orthopair fuzzy sets. Inf Fus 38:65–73
Yager RR (2013) Pythagorean fuzzy subsets. In 2013 joint IFSA world congress and NAFIPS annual meeting (IFSA/NAFIPS). IEEE, pp 57–61
Yang F, Kalkavan H, Dinçer H, Yüksel S, Eti S (2021) Gaussian-based soft computing approach to alternative banking system for sustainable financial sector. Complexity 2021
Yoon K, Hwang CL (1980) TOPSIS (Technique for Order Preference by Similarity to Ideal Solution—a multiple attribute decision making), vol 186. Springer, Berlin
Yücenur GN, Ipekçi A (2021) SWARA/WASPAS methods for a marine current energy plant location selection problem. Renew Energy 163:1287–1298
Yüksel S, Mikhaylov A, Khomyakova L (2021) Energy center selection in G7 industry with fuzzy MOORA. In: Handbook of research on strategic management for current energy investments. IGI Global, pp 87–106
Zhang Y, Tian Y (2021) Choice of pricing and marketing strategies in reward-based crowdfunding campaigns. Decis Support Syst 144:113520
Zheng Y, Mian SA, Wang Y (2022) The strategic entrepreneurship pitching on crowdfunding platforms: a traction toward emerging advanced technologies. In Strategic entrepreneurship. Springer, Cham, pp 207–230

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