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Analysis of environmental priorities for green project investments using an integrated q-rung orthopair fuzzy modelling

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ABSTRACT Green energy projects contribute to sustainable economic development of countries with the employment of environmentally friendly energy production strategies. However, environmental priorities should be examined for this situation. Therefore, priority analysis should be executed for the environmental issues while implementing green investment projects. Accordingly, this study aims at proposing a unique decision-making model based on orthopair fuzzy sets and the golden cut degrees for the environmental priorities of green project investments. The main novelty of the study stems from its proposed integrated model by equipping the Multi-SWARA, and TOPSIS based on the q-ROFSs technique with the golden cut. A set of criteria is identified for measuring the green projects' environmental priorities while several project alternatives are also determined with the supporting literature. Appropriately, the extensions of Multi-SWARA and TOPSIS methods have been applied for weighting and ranking the factors, respectively, in the integrated approach. Additionally, a comparative evaluation is performed with the help of VIKOR method to rank the alternatives. Besides, the sensitivity analysis is applied to illustrate the coherency of the weighting results in the decision-making approach. Accordingly, 5 cases are considered to measure the effects of changing weight results. It is defined that this model is coherent and could be extended for further studies. It is concluded that the reduction of emissions is the most essential item for the environmental priorities of green project investments. Pollution control, waste management and eco-friendly transportation activities are the most critical alternatives. Therefore, this study recommends that investors of green projects should prioritize the strategies of minimizing carbon emissions problem. In this context, investing in renewable energy technologies will help green project investors solve this problem.

INDEX TERMS Environmental priorities; Green Project; q-rung orthopair fuzzy sets; The golden cut

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I. INTRODUCTION

Green projects have a very high significance for the development of countries. This is because they support the development of alternative energy types to fossil fuels, such as the use of renewable energy. Therefore, owing to these projects, carbon emission rates can be minimized. On the other side, green projects also focus on energy efficiency and savings for businesses. For instance, in some of these projects, studies are carried out to increase efficiency in electric motors. Furthermore, green energy projects aim to effectively manage waste [1]. In this way, measures should be taken to protect the environment during the production process. So, it is possible to achieve economic development with environmentally friendly energy production owing to green projects.

Hence, green energy investments projects should be improved. However, environmental priorities should be evaluated for this condition. For instance, green energy projects can focus on the appropriateness of land use. In addition to this issue, a variety of the renewable energy sources can also minimize the risks in this process. Since each type of renewable energy has its disadvantages, diversifying these types will contribute to more effective management of these problems [2]. Green energy project investments may also aim to reduce carbon emissions. For this purpose, necessary investments should be made for renewable energy or carbon capture technologies. Moreover, there should be water and waste control systems in green project investments.

Priority analysis should be made for the environmental issues while implementing green investment projects. This situation helps the investors to use the budget more efficiently. Otherwise, making different improvements simultaneously create high costs for the companies that threaten the Sustainability of these projects. Therefore, multi-criteria decision-making (MCDM) approaches were considered by various scholars for criteria weighting and alternative ranking [3]. For instance, AHP and DEMATEL methods were used with the aim of finding the SWARA model was also considered for the same purposes [6]. On the other side, some researchers also used TOPSIS and VIKOR models to rank alternatives [7,8].

In this study, environmental priorities are evaluated for green project investments. Hence, it is aimed to identify the most significant environmental issues for the green project investors. In this scope, a unique model is generated using orthopair fuzzy sets and the golden cut membership and non-membership degrees. First, criteria are examined with the MSWARA based on the q-ROFSs with the golden cut. After that, in the second stage, six alternatives are ranked for green project investments with the help of TOPSIS methodology by q-ROFSs with the golden cut.

Additionally, a comparative evaluation has also been performed with the help of the VIKOR method to rank the alternatives. Besides, the sensitivity analysis has also been applied to illustrate the weighting results' coherency in the decision-making approach. Accordingly, 5 cases are considered to measure the effects of changing weight results. Therefore, the novelty of this study is its ability to create an integrated model by considering the Multi-SWARA, TOPSIS and VIKOR based on the q-ROFSs with the golden cut.

Identifying environmental priorities for green energy projects is a complex and critical issue. Hence, a comprehensive evaluation should be conducted to reach this objective. Because of this issue, different factors should be considered simultaneously, such as appropriateness of land use, variety of renewable energy sources, ecological protection, and reduction of emission. However, more essential items should also be defined in this regard. Otherwise, it will be very costly for green energy investors to take appropriate action. Thus, it is identified that there is a strong need to create a novel decision-making model to weigh this situation's criteria. Due to these reasons, in this study, a new decision-making model is constructed by considering M-SWARA, TOPSIS and VIKOR approaches based on q-ROFS and the golden cut.

The proposed model also has some advantages by comparing previously generated models in the literature. In this model, a new technique is created by the name of M-SWARA while making some significant improvements to the classical SWARA methodology. Owing to these new improvements, the causal evaluation among the items can also be identified in addition to the criteria weighting. This situation provides a vital superiority for this proposed model compared with previous similar models. Furthermore, in the calculation process of the degrees in q-ROFSs, the golden cut consideration. This situation has a decisive contribution to the originality of the proposed model. Additionally, uncertainty in the decision-making process can be handled more appropriately.

Moreover, q-ROFSs are generated by integrating IFS and PFS. They also consider a wider space in decision-making process to reach more effective solutions while comparing other models generated with IFS or PFS [4]. Moreover, the main reason of selecting the TOPSIS is its ability to rank the alternatives considering both negative and positive solutions [7]. This situation helps to make a more comprehensive evaluation compared to some other literature models. On the other side, a comparative evaluation has also been performed with the help of the VIKOR method to rank the alternatives. Hence, the coherency of the analysis results can be checked. Additionally, the sensitivity analysis has also been applied for illustrating the reliability of the weighting results in the decision-making approach by considering five different cases.

This paper organizes as follows; the second part reviews the conceptual background and empirical studies that shed a light on linkage between theory and practice. The third part introduces the background information on research and

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methodology. Following the analysis and findings of the study, authors provide discussions. Finally, this paper concludes with key points, recommendations, future research directions and limitations.

II. LITERATURE REVIEW

The subject of green energy projects has comprehensive literature. Some of these studies evaluated the importance of energy efficiency in these projects. Energy efficiency plays a pivotal role in considering environmental issues. In this framework, energy efficiency is the goal of reducing the amount of energy required to provide products and services [9]. It is important to use machines that consume less energy within this scope. In this way, the same process can be done with lessen energy consumption [10]. In this way, less energy will be used, which will help less damage to the environment. Li et al. [11] focused on the energy efficiency in China by using data envelopment methodology. They discussed that green project investors should mainly give information to increase energy efficiency. Liu et al. [12] evaluated the relationship between energy efficiency and renewable energy generation. Jin et al. [13] aimed to define appropriate strategies for the sustainable green economy. It is concluded that companies should consider energy efficiency for the effectiveness of green project investments.

The variety of renewable energy sources is also a significant issue concerning the environmental priorities of green project investments. They have a positive influence on solving environmental problems [14]. For instance, the carbon emissions problem mainly caused by fossil fuels can be minimized by using renewable energy sources. However, renewable energy types also have some disadvantages [15]. In this framework, lower energy is produced with solar energy when the sun goes down.

Similarly, the energy generation from the wind panels is not stable because it depends on the power of the wind. Because of these uncertainties, green project investors should focus on diversifying the renewable energy usage [16]. Owing to this situation, it will be easier to ensure stability in clean energy production. Pillai et al. [17] aimed to evaluate energy usage in buildings. They claimed that for the effectiveness of the green project investments, clean energy should be considered, and the verification of this energy should be provided. Fusco [18] focused on the robust techniques in smart grid control. In this study, it is also highlighted that green project investors should give importance to the diversification of the renewable energy usage. Falvo et al. [19] evaluated the Italian energy market. They also concluded that the verification of clean energy usage should be provided for the success of green energy investment projects.

Another important subject regarding the environmental prioritization for green project investment is carbon emission problem. The carbon emission is one of the most critical problems of today [20]. The carbon emissions cause an increase in the problem of global warming. It leads to the deterioration of the climate balance of the world [21]. One of the most important reasons for carbon emissions is the preference of fossil fuels in energy production. Therefore, care should be taken to minimize carbon emissions in green project investments [22]. In this context, renewable energy types can be used instead of fossil fuels. In addition, thanks to carbon capture and capture technologies, it is possible to reduce the carbon emissions problem [23]. Rupp et al. [24] determined that the carbon emissions problem should be solved for the success of clean project investments. Yang et al. [25] tried to examine the agriculture carbon emissions problem in China. They determined that renewable energy technology investments should be improved to take the cast advantage so that carbon emission problem can be solved more effectively. Wang et al. [26] also reached a similar conclusion in their analysis.

Furthermore, raising concerns on the climate change and global warming spotlighted the importance of green project investments. Studies mainly focused on these items to improve the performance of these investments. Nevertheless, there is a need for a new analysis that considers environmental priorities for green project investments. This analysis can be constructive for the investors to focus on more significant issues to increase the performance of these projects. Therefore, this manuscript aims to create a unique approach based on orthopair fuzzy sets and golden cut degrees for the environmental priorities of green project investments.

III. METHODOLOGY

This section introduces a hybrid model of q-ROFs with the golden cut, M-SWARA, TOPSIS and VIKOR approaches, containing the details on its design, procedures and computations.

A. Q-ROFs with the golden cut

IFS uses membership $\mu_I(\vartheta)$ and non-membership $n_I(\vartheta)$ degrees in the decision-making process with the condition of $0 \leq \mu_I(\vartheta) + n_I(\vartheta) \leq 1$. These sets are shown in Equation (1) [27].

$$I = \{\langle \vartheta, \mu_I(\vartheta), n_I(\vartheta)\rangle / \vartheta \epsilon U\} \quad (1)$$

PFS also considers membership and non-membership parameters (μ_P and n_P) to cope with uncertainty problems effectively. Equation (2) states the details of these sets [28].

$$P = \{\langle \vartheta, \mu_P(\vartheta), n_P(\vartheta)\rangle / \vartheta \epsilon U\} \quad (2)$$

Equation (3) demonstrates the condition.

$$0 \leq (\mu_P(\vartheta))^2 + (n_P(\vartheta))^2 \leq 1 \quad (3)$$

q-ROFSs are generated by extending I and P to reach better solution in this process by using parameters of μ_Q and n_Q. The details are given in Equation (4) [29].

$$Q = \{\langle \vartheta, \mu_Q(\vartheta), n_Q(\vartheta)\rangle / \vartheta \epsilon U\} \quad (4)$$

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The condition is demonstrated in Equation (5).

$$0 \le \left(\mu_Q(\vartheta)\right)^q + \left(n_Q(\vartheta)\right)^q \le 1\,,\ q \ge 1 \tag{5}$$

Equation (6) states the degree of indeterminacy [30].

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

Operations are shown in Equations (7)-(11) [31].

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

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

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

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

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

Defuzzification is made by Equation (12).

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

However, one of the most prominent issues in the fuzzy decision-making models is to determine the degrees properly. Fuzzy preferences are generally defined by only considering the important limitations of the selected fuzzy methodology, such as the sum of membership and non-membership degrees. Indeed, the optimal rate and sum of degrees for the fuzzy sets could be explained by using the assumptions of the golden ratio more accurately. The golden ratio is also known as the golden cut and gives information about the specific patterns of geometry problems. The Greek mathematicians and the latter theoreticians in the ancient times investigated the golden cut has been firstly to discover the the ratio of geometrical figures. The following academicians have redefined the golden cut by associating the Fibonacci numbers with the golden ratio [32,33]. The golden cut can be defined with the division of extreme and mean ratio in a straight line including the large and small quantities as in Equation (13).

$$\varphi = \frac{1+\sqrt{5}}{2} = 1.618\ldots \tag{13}$$

The golden cut-based member μ_G and non-membership n_G degrees could be defined as in Equation (14).

$$\varphi = \frac{\mu_G}{n_G} \tag{14}$$

Accordingly, the q-rung orthopair fuzzy sets with the golden cut can be revitalized by Equations (15) and (16). In these equations, μ_{Q_G} and n_{Q_G} are the q-rung orthopair membership and non-membership degrees with the golden cut, respectively.

$$Q_G = \{\langle \vartheta, \mu_{Q_G}(\vartheta), n_{Q_G}(\vartheta)\rangle / \vartheta \epsilon U\} \tag{15}$$

$$\mathbf{0} \le \left(\boldsymbol{\mu_{Q_G}(\vartheta)}\right)^{\boldsymbol{q}} + \left(\boldsymbol{n_{Q_G}(\vartheta)}\right)^{\boldsymbol{q}} \le \mathbf{1}\,,\quad \boldsymbol{q} \ge \mathbf{1} \tag{16}$$

B. M-SWARA method with q-ROFSs

The SWARA approach is used to weight the factors. In this context, the hierarchical priorities of the experts with the significance ratio are considered to evaluate the items. This study proposes multi-SWARA (an extension of SWARA) to identify the weights and relation degrees. First, a relation matrix is generated with the evaluations of the experts [34]. Second, the relations matrix is constructed as in Equation (17).

$$Q_k = \begin{bmatrix} 0 & Q_{12} & \cdots & \cdots & Q_{1n} \\ Q_{21} & 0 & \cdots & \cdots & Q_{2n} \\ \vdots & \vdots & \ddots & \cdots & \cdots \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ Q_{n1} & Q_{n2} & \cdots & \cdots & 0 \end{bmatrix} \tag{17}$$

Third, q-ROFSs are developed and score functions are calculated. Fourth, s_j, k_j, q_j,and w_j values are computed by Equations (18)-(20). Within this scope, k_j indicates coefficient, s_j represents comparative importance rate, w_j states the weights and q_j identifies the recalculated weight.

$$k_j = \begin{cases} 1 & j = 1 \\ s_j + 1 & j > 1 \end{cases} \tag{18}$$

$$q_j = \begin{cases} 1 & j = 1 \\ \frac{q_{j-1}}{k_j} & j > 1 \end{cases} \tag{19}$$

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

$$w_j = \frac{q_j}{\sum_{k=1}^{n} q_k} \tag{20}$$

Fifth, stables values in the matrix are determined. For this purpose, the matrix is limited and transposed to the power of 2t+1. Sixth, with the threshold values, impact directions are defined.

C. TOPSIS with q-ROFSs

TOPSIS ranks alternatives by considering the weights of the factors. First, expert evaluations are obtained [35]. Second, the decision matrix is created with Equation (21).

$$X_k = \begin{bmatrix} 0 & X_{12} & \cdots & \cdots & X_{1m} \\ X_{21} & 0 & \cdots & \cdots & X_{2m} \\ \vdots & \vdots & \ddots & \cdots & \cdots \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ X_{n1} & X_{n2} & \cdots & \cdots & 0 \end{bmatrix} \tag{21}$$

Third, q-ROFSs are developed and score functions are calculated. Fourth, normalized values are defined as in Equation (22).

$$r_{ij} = \frac{X_{ij}}{\sqrt{\sum_{i=1}^{m} X_{ij}^2}}. \tag{22}$$

Weighted values are computed by Equation (23) [36].

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$$v_{ij} = w_{ij} \times r_{ij}. \tag{23}$$

Equations (24) and (25) show the calculation of positive and negative (A^+, A^-) solutions.

$$A^+ = \{v_{1j}, v_{2j}, \dots, v_{mj}\} = \{\max v_{1j}\ for\ \forall\ j \in n\}, \tag{24}$$

$$A^- = \{v_{1j}, v_{2j}, \dots, v_{mj}\} = \{\min v_{1j}\ for\ \forall\ j \in n\}. \tag{25}$$

Equations (26) and (27) are used to calculate the distances to the best (D_i^+) and worst solutions.

$$D_i^+ = \sqrt{\sum_{j=1}^{n} \left(v_{ij} - A_j^+\right)^2} \tag{26}$$

$$D_i^- = \sqrt{\sum_{j=1}^{n} \left(v_{ij} - A_j^-\right)^2} \tag{27}$$

Relative closeness to the ideal solutions (RC_i) is computed in formula (28) [37].

$$RC_i = \frac{D_i^-}{D_i^+ + D_i^-}. \tag{28}$$

D. VIKOR with q-ROFSs

VIKOR is considered with the aim of ranking different alternatives. In the calculation process, fuzzy best and worst values ($\tilde{f}_j^{\,*}, \tilde{f}_j^{\,-}$) are taken into consideration. Equation (29) gives information about the details of these values [38].

$$\tilde{f}_j^* = \max_i \tilde{x}_{ij}, \text{ and } \tilde{f}_j^- = \min_i \tilde{x}_{ij} \tag{29}$$

Mean group utility ($\tilde{S}_i$) and maximal regret ($\tilde{R}_i$) are calculated in the next process. For this purpose, Equations (30) and (31) are considered. Within this framework, $\widetilde{w}_j$ refers to the fuzzy weights [39].

$$\tilde{S}_i = \sum_{i=1}^{n} \widetilde{w}_j \frac{\left(\left|\tilde{f}_j^{\,*} - \tilde{x}_{ij}\right|\right)}{\left(\left|\tilde{f}_j^{\,*} - \tilde{f}_j^{\,-}\right|\right)} \tag{30}$$

$$\tilde{R}_i = \max_j \left[\widetilde{w}_j \frac{\left(\left|\tilde{f}_j^{\,*} - \tilde{x}_{ij}\right|\right)}{\left(\left|\tilde{f}_j^{\,*} - \tilde{f}_j^{\,-}\right|\right)}\right] \tag{31}$$

Equation (32) gives information about the computation of the $\tilde{Q}_i$. In this context, v represents the strategy weights. On the other side, 1-v demonstrates regret.

$$\tilde{Q}_i = v\left(\tilde{S}_i - \tilde{S}^*\right)/\left(\tilde{S}^- - \tilde{S}^*\right) + (1-v)\left(\tilde{R}_i - \tilde{R}^*\right)/\left(\tilde{R}^- - \tilde{R}^*\right) \tag{32}$$

These values are used for the purpose of ranking different alternatives.

IV. ANALYSIS RESULTS

Environmental priorities of green project investments are examined in this manuscript. For this purpose, a new model is constructed by considering the Multi-SWARA, TOPSIS based on q-ROFSs with the golden cut. The details are illustrated in Figure 1.

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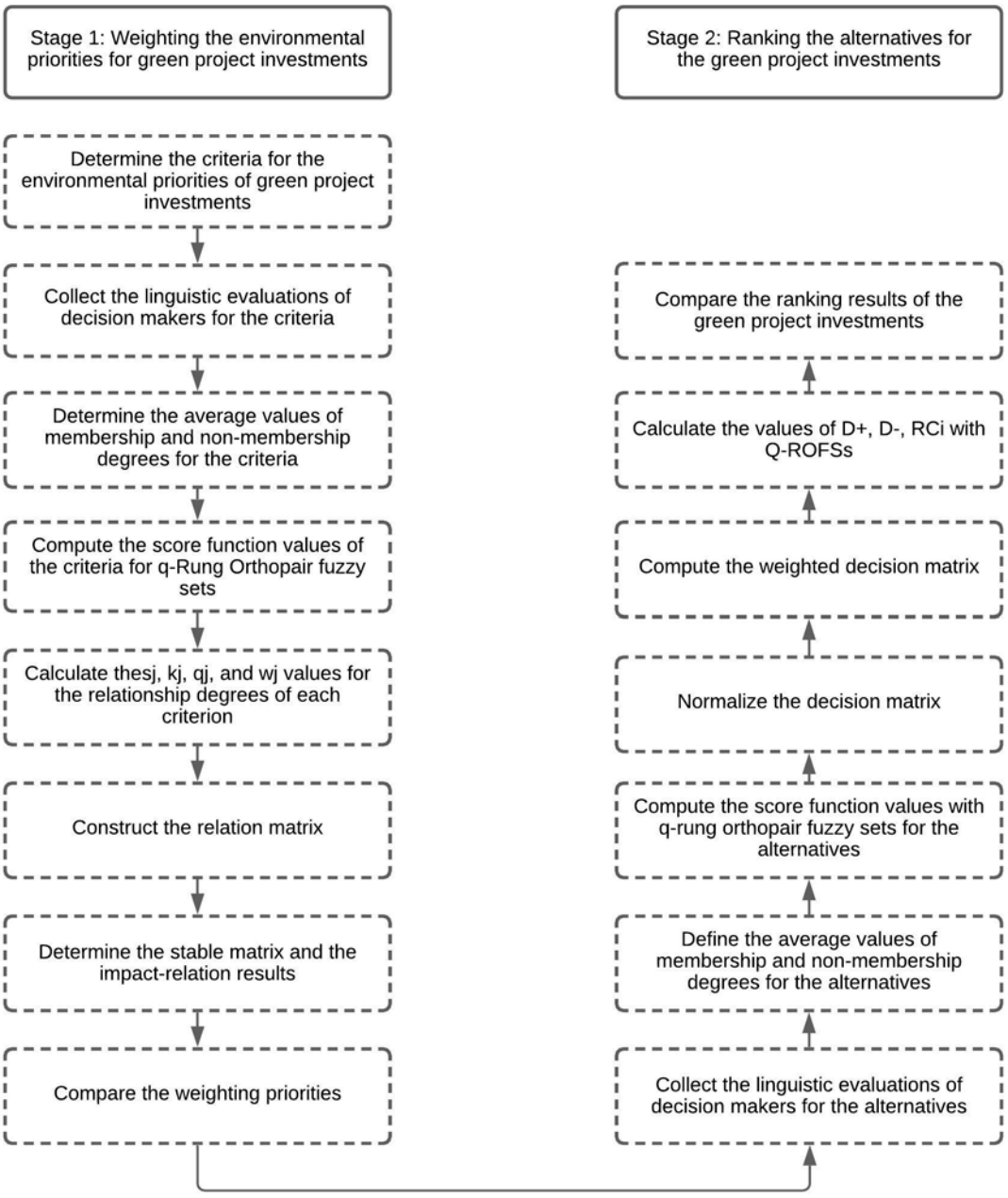


FIGURE 1. **The flowchart**

Stage 1: Weighting the environmental priorities for green project investments.

Step 1: Selecting the factors

First, the criteria are selected in Table 1.

TABLE 1. **Selected criteria**

Items	Literature
Appropriateness of land use (Criterion 1)	[15]
Variety of renewable energy sources (Criterion 2)	[13]
Ecological protection (Criterion 3)	[11]
Reduction of emission (Criterion 4)	[12]
Water and waste control (Criterion 5)	[16]

Source: The criteria are adapted from the Green Project Mapping of ICMA at https://www.icmagroup.org/assets/documents/Sustainable-finance/2021-updates/Green-Project-Mapping-June-2021-100621.pdf

Appropriateness of land use is an essential environmental priority for green project investments. Additionally, renewable energy sources can be varied to achieve this objective. Next, ecological protection plays a vital-role in this respect. Then, reduction of the emission has a positive contribution to this issue. Finally, water and waste control help to achieve this objective.

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Step 2: Evaluations are obtained

After that, expert opinions are provided. In this scope, the expert team includes three different people who have more than 21-year experience. Moreover, they have coordinated various projects regarding the environmental priorities for the green project investments. For this purpose, linguistic scales stated in Table 2 are used.

TABLE 2. Linguistic scales

Scales for Criteria	Scales for Alternatives	Membership Degrees	Non-membership Degrees
no (n)	worst (w)	.40	.25
some (s)	low (p)	.45	.28
medium (m)	normal (f)	.50	.31
high (h)	powerful (g)	.55	.34
very high (vh)	perfect (b)	.60	.37

Table 3 includes evaluations.

TABLE 3. Evaluations

Expert 1					
	C1	**C2**	**C3**	**C4**	**C5**
C1		N	VH	H	M
C2	N		M	VH	VH
C3	M	VH		N	M
C4	M	VH	VH		VH
C5	VH	M	M	VH	
Expert 2					
	C1	**C2**	**C3**	**C4**	**C5**
C1		N	M	H	M
C2	M		VH	M	M
C3	VH	VH		VH	VH
C4	M	VH	VH		VH
C5	VH	M	M	VH	
Expert 3					
	C1	**C2**	**C3**	**C4**	**C5**
C1		S	S	H	S
C2	M		VH	M	M
C3	VH	VH		VH	VH
C4	M	VH	VH		S
C5	S	M	S	VH	

Step 3: Average values are calculated.

Average values are given in Table 4.

TABLE 4. Average values

	C1		C2		C3		C4		C5	
	μ	**v**	**M**	**v**	**μ**	**v**	**μ**	**v**	**μ**	**v**
C1			.42	.26	.52	.32	.55	.34	.48	.30
C2	.47	.29			.57	.35	.53	.33	.53	.33
C3	.57	.35	.60	.37			.53	.33	.57	.35
C4	.50	.31	.60	.37	.60	.37			.55	.34
C5	.55	.34	.50	.31	.48	.30	.60	.37		

Step 4: Score function values are calculated.

Table 5 states the score function values.

TABLE 5. Linguistic scales

	C1	**C2**	**C3**	**C4**	**C5**
C1	.000	.055	.105	.127	.086
C2	.078	.000	.139	.116	.116
C3	.139	.165	.000	.116	.139
C4	.095	.165	.165	.000	.127
C5	.127	.095	.086	.165	.000

Step 5: The values of s_j, k_j, q_j, and w_j are computed.

Next, Table 6 includes the values of s_j, k_j, q_j, and w_j.

TABLE 6. sj, kj, qj, and wj

C1	**Sj**	**kj**	**qj**	**wj**	**C2**	**Sj**	**kj**	**qj**	**wj**
C4	.127	1.000	1.000	.284	C3	.139	1.000	1.000	.276
C3	.105	1.105	.905	.257	C4	.116	1.116	.896	.247
C5	.086	1.086	.833	.236	C5	.116	1.116	.896	.247
C2	.055	1.055	.789	.224	C1	.078	1.078	.832	.229
C3	**Sj**	**kj**	**qj**	**wj**	**C4**	**Sj**	**kj**	**qj**	**wj**
C2	.165	1.000	1.000	.282	C2	.165	1.000	1.000	.270
C1	.139	1.139	.878	.248	C3	.165	1.165	1.000	.270
C5	.139	1.139	.878	.248	C5	.127	1.127	.887	.240
C4	.116	1.116	.787	.222	C1	.095	1.095	.810	.219
C5	**Sj**	**kj**	**qj**	**wj**					
C4	.165	1.000	1.000	.290					
C1	.127	1.127	.887	.258					
C2	.095	1.095	.810	.235					
C3	.086	1.086	.746	.217					

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Step 6: Relation matrix is created.

Relation matrix is created in Table 7.

TABLE 7. Relation matrix

	C1	C2	C3	C4	C5
C1		.224	.257	.284	.236
C2	.229		.276	.247	.247
C3	.248	.282		.222	.248
C4	.219	.270	.270		.240
C5	.258	.235	.217	.290	

Step 7: Stable matrix is constructed.

Table 8 includes the stable matrix

TABLE 8. Stable matrix

	C1	C2	C3	C4	C5
C1	.192	.192	.192	.192	.192
C2	.202	.202	.202	.202	.202
C3	.203	.203	.203	.203	.203
C4	.207	.207	.207	.207	.207
C5	.195	.195	.195	.195	.195

Step 8: Weighting priorities are defined.

Figure 2 explains impact-relation.

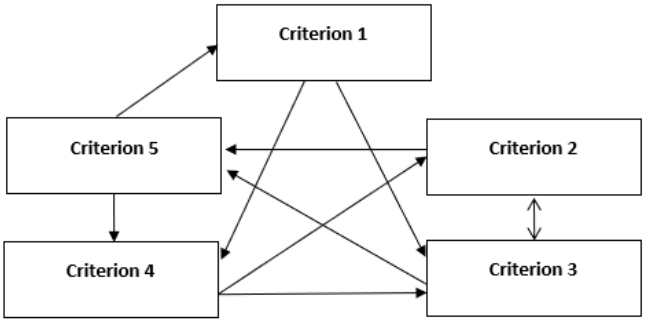


FIGURE 2. Impact-relation map

Weighted priorities are given in Table 9.

TABLE 9. Comparative weighting priorities

	IFSs	PFSs	q-ROFSs
C1	5	5	5
C2	3	3	3
C3	2	2	2
C4	1	1	1
C5	4	4	4

The ranking results are similar for both q-ROFs, IFSs and PFSs. It is seen that the findings are coherent. It is concluded that the reduction of emissions is an essential item for the environmental priorities of green project investments. Furthermore, ecological protection also plays a key role in this situation. However, the appropriateness of land use has the lowest weight.

Stage 2: Alternatives are ranked.

Step 9: Evaluations are provided.

In the second stage, alternatives are ranked for green project investments. In this context, selected alternatives are shown in Table 10.

TABLE 10. Selected alternatives

Factors	References
Energy generation and efficiency (Alternative 1)	[20]
Land use and ecological protection (Alternative 2)	[19]
Pollution control and waste management (Alternative 3)	[17]
Eco-friendly transportation activities (Alternative 4)	[21]
Technologies of circular manufacturing (Alternative 5)	[18]
Green buildings (Alternative 6)	[16]

For the effectiveness of the green project investments, companies can focus on energy generation and efficiency. Also, land use and ecological protection t can be considered. Pollution control and waste management are the other alternatives for this purpose. Furthermore, eco-friendly transportation activities can be another significant green project investment alternative. Companies can also improve the technologies of circular manufacturing. Finally, companies may create green buildings. Table 11 identifies the evaluations.

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TABLE 11. Evaluations

Expert 1					
	C1	**C2**	**C3**	**C4**	**C5**
A1	B	W	W	P	G
A2	W	P	F	F	B
A3	P	F	B	B	W
A4	B	W	P	F	B
A5	G	W	F	B	F
A6	B	F	W	B	F
Expert 2					
	C1	**C2**	**C3**	**C4**	**C5**
A1	B	W	W	F	B
A2	W	F	F	F	B
A3	F	F	B	B	W
A4	B	W	P	B	B
A5	B	W	F	B	F
A6	B	F	W	B	F
Expert 3					
	C1	**C2**	**C3**	**C4**	**C5**
A1	B	W	W	F	B
A2	F	F	F	F	B
A3	F	F	B	F	W
A4	B	W	F	B	B
A5	F	W	F	B	F
A6	F	F	W	B	F

Step 10: Average values are computed.

Average values are shown in Table 12.

TABLE 12. Evaluations

	C1		**C2**		**C3**		**C4**		**C5**	
	μ	**v**	**μ**	**v**	**μ**	**v**	**μ**	**v**	**μ**	**v**
A1	.60	.37	.40	.25	.40	.25	.48	.30	.58	.36
A2	.43	.27	.48	.30	.50	.31	.50	.31	.60	.37
A3	.48	.30	.50	.31	.60	.37	.57	.35	.40	.25
A4	.60	.37	.40	.25	.47	.29	.57	.35	.60	.37
A5	.55	.34	.40	.25	.50	.31	.60	.37	.50	.31
A6	.57	.35	.50	.31	.40	.25	.60	.37	.50	.31

Step 11: Score function values are defined.

Table 13 includes the details of score functions.

TABLE 13. Score functions

	C1	**C2**	**C3**	**C4**	**C5**
A1	.165	.049	.049	.086	.152
A2	.062	.086	.095	.095	.165
A3	.086	.095	.165	.139	.049
A4	.165	.049	.078	.139	.165
A5	.127	.049	.095	.165	.095
A6	.139	.095	.049	.165	.095

Step 12: Matrix is normalized.

The values are normalized as in Table 14.

TABLE 14. Normalized Matrix

	C1	**C2**	**C3**	**C4**	**C5**
A1	.519	.270	.206	.260	.484
A2	.195	.476	.403	.288	.527
A3	.271	.527	.696	.420	.156
A4	.519	.270	.327	.420	.527
A5	.399	.270	.403	.498	.305
A6	.437	.527	.206	.498	.305

Step 13: Weighted matrix is created.

Table 15 states weighted matrix.

TABLE 15. Weighted Matrix

	C1	**C2**	**C3**	**C4**	**C5**
A1	.100	.055	.042	.054	.095
A2	.038	.096	.082	.060	.103
A3	.052	.107	.141	.087	.031
A4	.100	.055	.067	.087	.103
A5	.077	.055	.082	.103	.060
A6	.084	.107	.042	.103	.060

Step 14: The values of D+, D-, RCi are determined.

D+, D-, RCi values are computed as in Table 16.

TABLE 16. D+, D-, RCi values

Alternatives	**D+**	**D-**	**RCi**
A1	.123	.089	.421
A2	.097	.093	.489
A3	.088	.118	.572
A4	.093	.104	.529
A5	.093	.080	.462
A6	.110	.090	.451

Step 15: Comparative ranking is performed.

Ranking results of the green project investments are indicated in Table 17.

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TABLE 17. Comparative ranking results

Alternatives	q-ROF Multi SWARA-TOPSIS	PF Multi SWARA-TOPSIS	IF Multi SWARA-TOPSIS	q-ROF Multi SWARA-VIKOR	PF Multi SWARA-VIKOR	IF Multi SWARA-VIKOR
A1	6	6	6	6	6	6
A2	3	3	3	3	3	3
A3	1	1	2	1	1	1
A4	2	2	1	2	2	2
A5	4	4	4	4	5	5
A6	5	5	5	5	4	4

The comparative rankings result with the TOPSIS and VIKOR are very similar for all models. Therefore, it is identified that the results are reliable. The findings demonstrate that pollution control, waste management and eco-friendly transportation activities are critical alternatives. Energy generation, efficiency and green buildings take place on the last ranks.

Additionally, the sensitivity analysis is applied to illustrate the weighting results' coherency in the decision-making approach. Accordingly, 5 cases are considered to measure the effects of changing weight results, and the consecutive ranking performances are represented for both the extended methods of TOPSIS and VIKOR in Table 18.

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TABLE 18. Sensitivity analysis results

Case 1						
Alternatives	**q-ROF Multi SWARA-TOPSIS**	**PF Multi SWARA-TOPSIS**	**IF Multi SWARA-TOPSIS**	**q-ROF Multi SWARA-VIKOR**	**PF Multi SWARA-VIKOR**	**IF Multi SWARA-VIKOR**
A1	6	6	6	6	6	6
A2	3	3	3	3	3	3
A3	1	1	2	1	1	1
A4	2	2	1	2	2	2
A5	4	4	4	4	5	5
A6	5	5	5	5	4	4
Case 2						
Alternatives	**q-ROF Multi SWARA-TOPSIS**	**PF Multi SWARA-TOPSIS**	**IF Multi SWARA-TOPSIS**	**q-ROF Multi SWARA-VIKOR**	**PF Multi SWARA-VIKOR**	**IF Multi SWARA-VIKOR**
A1	6	6	6	6	6	6
A2	3	3	2	3	3	2
A3	1	1	3	1	1	1
A4	2	2	1	2	2	3
A5	4	4	4	4	5	5
A6	5	5	5	5	4	4
Case 3						
Alternatives	**q-ROF Multi SWARA-TOPSIS**	**PF Multi SWARA-TOPSIS**	**IF Multi SWARA-TOPSIS**	**q-ROF Multi SWARA-VIKOR**	**PF Multi SWARA-VIKOR**	**IF Multi SWARA-VIKOR**
A1	6	6	6	6	6	6
A2	3	2	2	3	2	2
A3	1	1	1	1	1	1
A4	2	3	3	2	3	3
A5	4	4	4	4	5	5
A6	5	5	5	5	4	4
Case 4						
Alternatives	**q-ROF Multi SWARA-TOPSIS**	**PF Multi SWARA-TOPSIS**	**IF Multi SWARA-TOPSIS**	**q-ROF Multi SWARA-VIKOR**	**PF Multi SWARA-VIKOR**	**IF Multi SWARA-VIKOR**
A1	6	6	6	6	6	6
A2	3	3	2	3	3	2
A3	1	1	3	1	1	1
A4	2	2	1	2	2	3
A5	4	4	4	4	5	5
A6	5	5	5	5	4	4
Case 5						
Alternatives	**q-ROF Multi SWARA-TOPSIS**	**PF Multi SWARA-TOPSIS**	**IF Multi SWARA-TOPSIS**	**q-ROF Multi SWARA-VIKOR**	**PF Multi SWARA-VIKOR**	**IF Multi SWARA-VIKOR**
A1	6	6	6	6	6	6
A2	3	3	3	3	3	3
A3	1	1	2	1	1	1
A4	2	2	1	2	2	2
A5	4	4	4	4	5	5
A6	5	5	5	5	4	4

As seen in Table 18, the sensitivity analysis results are also consistent in the case of changing weights of criteria

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consecutively. This is clear evidence that the proposed decision-making approach could be applicable for the further extensions of the complex fuzzy-based modelling.

V. DISCUSSIONS

Green project investors should prioritize the strategies to minimize the carbon emissions problem. Within this framework, they should focus on improvement of the renewable energy projects. The carbon emissions resulting from fossil fuels pose a severe threat to the world. Environmental pollution caused by this problem causes critical health problems. It is also possible to highlight the catastrophic effects of both social and economic problems on sustainable development. The high number of people with health problems leads to a significant decrease in growing economies' workforce. Consequently, it will adversely affect the economic growth and stability. On the other hand, this situation also leads to an increase in overall health expenditures, causing a burden on the budgets of the countries. Therefore, it would be appropriate for investors to focus primarily on this problem in green projects. The use of renewable energy dramatically reduces the carbon emission problem. However, high costs also hinder the development of these projects. In this context, investing in renewable energy technologies will help green project investors to solve this problem.

In the literature, some scholars also underlined the importance of this issue. Within this framework, different suggestions are provided to minimize the carbon emissions problem. Tan et al. [40] aimed to examine energy efficiency based on data-driven approach. They discussed that carbon emission problem should be primarily solved for the effectiveness of green project investments. They stated that carbon capture technologies should be improved. Garavey et al. [41] focused on the scenarios for net-zero emissions in the UK steel sector. They claimed that necessary investments should be made for carbon capture and storage technologies. Thus, the success of green project investments can be increased.

On the other side, Pillai et al. [42] reviewed the building integrated photovoltaic systems. They concluded that companies should give significance to the renewable energy technology investments so that green projects can become more successful. Similarly, Kou et al. [43] aimed to create innovative carbon emission strategies. In this scope, solar energy-based transportation projects were taken into consideration. They discussed that companies should mainly prioritize the solar energy systems so that carbon emissions caused by the transportation industry can be minimized. Zhang et al. [44] and Dinçer et al. [45] also explained the significance of clean energy investment projects intending to minimize the carbon emissions. They mainly identified that companies should make investments in renewable energy technologies. In summary, carbon capture technologies and renewable energy technology investments play a pivotal role in decreasing carbon emissions, according to the studies in the literature.

VI. CONCLUSIONS

In this study, a set of criteria is identified to evaluate the environmental priorities of green projects. Moreover, several project alternatives are determined with the supporting literature. Also, the extensions of Multi-SWARA and TOPSIS are applied for weighting and ranking the factors, respectively, in the integrated model. The analysis results indicate that the integrated approach is coherent and reliable. It is defined that the reduction of the carbon emissions is an essential item for the environmental priorities of green project investments. Pollution control, waste management, and eco-friendly transportation activities are the most critical alternatives.

This study generated a novel analytics model integrating the MSWARA, TOPSIS based on the q-ROFSs with the golden cut. However, the main limitation of the study stems from the lack of project-based empirical data, which led researchers rely on the expert judgments with linguistic variables on general grounds for evaluation. For future studies, more specific examinations can be performed. For instance, a comprehensive evaluation can be executed to investigate appropriate strategies for minimizing the ruinous impact of the carbon emissions. The proposed model in this study also provides many benefits for policy makers, practitioners and investors as compared with the previous generated models employing traditional methods. Nonetheless, different MCDM models can also be used in the analysis process. For instance, intuitionistic fuzzy due methodology can be considered in this regard [46].

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