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ARTICLE

# Assessment of the Solid Waste Disposal Method during COVID-19 Period Using the ELECTRE III Method in an Interval-Valued q-Rung Orthopair Fuzzy Approach

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## ABSTRACT

As the quantity of garbage created every day rises, solid waste management has become the world's most important issue. As a result, improper solid waste disposal and major sanitary issues develop, which are only detected after they have become dangerous. Due to the system's lockdown during the COVID-19 pandemic, this scenario became much more uncertain. We are at the stage to develop and execute effective waste management procedures, as well as long-term policies and forward-thinking programmes that can work even in the most adverse of scenarios. We incorporate major solid waste (organic and inorganic solid wastes) approaches that actually perform well in normal cases by reducing waste and environmental disasters; however, in such an uncertain scenario like the COVID-19 pandemic, the project automatically allows for a larger number of criteria, all of which are dealt with using fuzzy Multi-Criteria Group Decision Making (MCGDM) methods. The ELECTRE III (ELimination Et Choice Translating REality-III) approach, which is a novel decision-making strategy for determining the best way to dispose and reduce garbage by combining traditional ELECTRE III with an interval-valued q-rung orthopair fuzzy set (IVq-ROFS), is described in detail in this article. To confirm the efficacy of the recommended model, a numerical explanation is provided, as well as sensitivity and comparative analyses. Obviously, the findings encourage decision-makers in authorities to deliberate about the proposals before creating solid waste management policies.

## KEYWORDS

MCDM; organic waste; inorganic waste; ELECTRE III; interval-valued q-rung orthopair fuzzy number

## 1 Introduction

Waste is in various forms like solid, fluid, or gas and each form of waste can be disposed of and purified by various methods. The management of waste deals with all forms of waste that pose the problems of waste disposal. The quantities of household and hospital waste are increasing day by day in the COVID-19 situation. Solid waste (SW) disposal in urban and rural areas appears to be one of the major issues currently faced by developed and developing countries during the lock-down period. Food waste, paper, plastic, metal, and glass, along with some harmful waste such as batteries, electric lights, parts of automobiles, and unused drugs, are the main wastes [1]. Solid waste may be categorized as organic waste and inorganic waste. Inappropriate handling of solid waste has various adverse effects such as degradation of natural resources, impact of soil pollution, groundwater pollution, air emissions and greenhouse gases (GHG), methane release, toxicity to humans and habitats [2]. The resulting GHG emissions, mainly $CO_2$, methane ($CH_4$), and nitrous oxide ($N_2O$), have significant adverse effects on people, through the potential for air pollution, ozone depletion, and global warming affects the public both directly and indirectly. In addition to being a social issue, solid waste disposal and management is a mixture of political, socio-cultural, technological, economic, and environmental influences. The choice of suitable technologies for the reduce/reuse and disposal of solid waste will also help to minimize waste and to maintain waste management in a good way during a pandemic period, resulting in environmental destruction, lack of hygiene, and a host of health issues being solved.

The key remedies are waste minimization and recycling, the management of hazardous air pollution in organic and inorganic waste incinerators, and alternative treatment and disposal practices. There is a range of available and evolving strategies for the disposal of solid wastes. Experts have emphasised the importance of reducing waste in order to save money and contribute to long-term waste management during the pandemic. Therefore, we need to concentrate on sustainable tactical approaches for solid waste collection and methods of waste disposal. Multi-criteria decision making (MCDM) is a crucial technique in decision-making assessment. An MCDM problem involves alternatives, criteria, criteria weights, and a decision matrix of alternatives. The elements of the decision matrix are the evaluator's estimates for each criterion, which are used to compare the alternatives. As a result, it is critical to conduct extensive research on decision-making issues in order to fully express the judgement matrix and the weights of criteria. Hence, the disposal methods of solid waste problem considered as a MCDM problem when the experts have hesitation to in selecting the disposal techniques. We cannot always provide consistent assessment values of alternatives for the indeterminacy of experts and decision-making challenges to choose the best way in actual MCDM issues. To tackle this drawback, the fuzzy set theory described by Zadeh [3] used the membership function to explain the results of the calculation rather than the exact real-number. Another classification index was introduced by Atanassov [4], which designated the non-membership feature as a complement.

The IFSs and PFSs can precisely describe uncertain information, there are still difficulties that IFSs and PFSs can handle. When an expert gives a degree of membership and a non-membership value of 0.8 and 0.9, respectively, they do not satisfy the conditions of PFSs such as $(0.8)^2 + (0.9)^2 = 1.45 > 1$. Yager introduced the q-rung orthopair fuzzy set (q-ROFS) concept [5], where the sum of the q-th power of the membership and q-th power non-membership is restricted to 1, that is $\theta^q + \phi^q = 1$. When q = 1 and q = 2, the q-ROFS reduces to IFS, and PFS, respectively. Here, the concept of a q-rung orthopair fuzzy set (q-ROFS) for this particular problem, which is more influential and general than IFS and PFS and deals with unstable and unpredictable data in the context of fuzzy set theory. We extend the q-ROFN into IV-q-ROFNs, which has more flexible than q-ROFN. For this solid waste disposal problem, we chose an interval valued q-rung orthopair fuzzy set which can be used to resolve the conditions where experts fail to determine options between the various potential membership and non-membership values [6]. The IVq-ROF set, defined as the sum of q-th power of membership and non-membership values, satisfies the constraint $(0 \leq [\theta_F^L(u), \theta_F^U(u)]^q + [\phi_F^L(u), \phi_F^U(u)]^q \leq 1)$. Hence, the interval-valued q-rung orthopair fuzzy set is clearly more reliable than the PFS in describing fuzziness and uncertainty. This realization draws more attention to the IVq-ROFS and motivates us to create new techniques under the q-ROFS. Researchers have recently proceeded to develop the MCDM method for the IVq-ROFS environment due to the benefits of the IVq-ROF set [7]. Therefore, IVq-ROFS can be considered as a great way to express evaluation results as compared to IFS and PFS. Here, we chosen ELECTRE III method for this disposal problem. The ELECTRE III (ELimination Et Choice Translating reality III) method is described by Figueira et al. [8]. The ELECTRE III approach has multiple priorities, compared to other MCDM strategies, and prioritizes experts in the ranking process using a weight vector. The ELECTRE III approach has also been used in other contexts, such as determining fuzzy binary relationships to represent group preferences. Hence, the proposed model is the best tool to obtain realistic decisions from the experts. For this paper is nomenclature with their abbreviations are given in Table 1.

**Table 1:** Nomenclature

| | |
|---|---|
| MCDM | Multi-criteria decision making |
| IFS | Intuitionistic fuzzy set |
| q-ROFN | q-rung orthopair fuzzy number |
| IVq-ROFN | Interval-valued q-rung orthopair fuzzy number |
| ELECTRE III | Elimination and choice translating reality III |
| SW | Solid waste |
| SWM | Solid waste management |
| MSW | Municipal solid waste |
| SL | Sanitary landfills |
| AD | Anaerobic digestion |
| AC | Aerobic composting |
| RC | Recycling |

## 2 Literature Review

In this section, some studies related to SW, MSW, MCDM, ELECTRE III, and some relevant works from different parts of the world about SWM. Kharat et al. [9] proposed a fuzzy TOPSIS approach to develop an effective decision support framework not only for the design of new MSWM systems but also for the improvement of existing MSWM systems to achieve lower costs and greater eligibility in terms of environmental, social, cultural, and legal attractiveness requirements. Singh et al. [10] have used the fuzzy approach in managing the uncertainty problems in waste disposal. Badi et al. [11] have discussed to selecting the suitable site for the MSW dumping for the city of Misurata. Luo et al. [12] constructed a novel MCGDM methodology to manage and rank sustainable scenarios for MSWM. Rahimi et al. [13] have suggested the group fuzzy MULTIMOORA approach to achieve the optimum alternative and have used the group fuzzy BMW method to find the required weights for disposal of MSW for Mahallat in sustainable landfill site selection. Aghajani Mir et al. [14] proposed an enriched version of the TOPSIS method to identify the SWM treatment techniques and compared the results with the VIKOR method. Meegoda et al. [15] proposed the processes, parameters, and optimization of anaerobic digestion (AD). To reduce device costs and carbon dioxide ($CO_2$) emissions arising from transport operations in position planning for MSWM systems, a bi-objective optimization MILP model is proposed by Mohsenizadeh et al. [16]. Fana et al. [17] have discussed the various approaches and stages in anaerobic digestion of MSW, which is used to maximize the production and efficiency of biogas. Coban et al. [18] have used TOPSIS, PROMETHEE-1 and PROMETHEE-II to find out the best suitable disposable techniques for the MSWM in Turkey. Kunwar et al. [19] provide an outline of numerous treatment approaches to increase methane yield of AD of organic fraction of municipal solid waste. The DEMATEL method for determining the weights of the parameters was developed by Wang et al. [20] and the interval-valued fuzzy grey relational analysis model was used to rank the MSW treatment scenarios. During the COVID-19 epidemic, Bhargavi et al. [21] suggested waste management activities and other ways for municipal solid waste care and disposal in a few established and growing nations. Malav et al. [22] discusses the problems of waste to energy projects in India. In addition, a range of guidelines are given to improve the handling of solid waste in India.

Here, we discuss the ELECTRE III method with various types of fuzzy sets. Chen et al. [23] proposed the MCGDM method based on ELECTRE III using probabilistic linguistic term set. Liao et al. [24] introduced the addition, subtraction and division operations for PLTSs and new beneficial algorithm for the PL-ELECTRE III method for solving a problem concerning the nurse?patient relationship. Chen et al. [25] developed a QFD and ELECTRE III-embedded hybrid MCGDM approach for sustainable building material selection under basic uncertain linguistic term set and the capability of BUI is extended in modeling the complex human reasoning. Mahmoudi et al. [26] investigated the use of a geographic information system (GIS) and multi-criteria evaluation (MCE) to locate a potential artificial recharge location for recovered water in Ariana, Tunisia. The ELECTRE III technique was utilized in this case to evaluate the potential places for aquifer recharge with treated water based on their features, which were weighted from highest to lowest: distance from the road, geometric structure of the area, cost of the location, and distance from marshlands. Based on the ELECTRE-III approach and a multiobjective evolutionary algorithm, a credit ranking model for parafinancial organisation is developed by Chavira et al. [27]. ELECTRE III is expanded with GIT2FSs to choose the finest MHE using a new ranking technique by Mohamadghasemi et al. [28]. Furthermore, GIT2FSs have access to various arithmetic operations and attributes and the suggested technique is used in a real life problem to highlight its possible applicability. Geetha et al. [29] presented the HPF-ELECTRE III method to determine the most adaptable recycling method for plastic materials. Ebadi Torkayesh et al. [30] analysed the complexities of waste-to-energy (WtE) planning as a solid waste treatment in Iran's Azerbaijan area. The VIKOR method is used to choose the optimal WtE technology within that scenario. The ELECTRE III approach is then used to choose a suitable installation spot. To establish the weights of the criterion, the Fuzzy entropy approach was devised. Mohamadghasemi et al. [31] expanded the ELECTRE III approach to interval type-2 fuzzy sets (IT2FSs) utilizing curved (such as Gaussian) membership functions. According to Akram et al. [32], PFS-based decision making enhances the capability of intuitionistic fuzzy set-based decision making, which has the vitality of the ELECTRE III approach. In the trapezoidal interval type-2 fuzzy set environment, Geetha et al. [33] enhanced the optimal MCDM in ELECTRE III. Choosing the best location for a mustard mill may be considered as a MCDM problem. Bhol et al. [34] employed and detailed the ELECTRE III technique to evaluate several site options in increasing order of appropriateness. Ding et al. [35] worked on MSW in eight eastern coastal regions of China, emphasizing on background information, relevant legislation, MSW characteristics, and TTRU. Yang et al. [36] conducted a thorough analysis of PM sampling and measurement methodologies, formation mechanisms, distribution, inorganic content, and variables impacting PM emission during coal/biomass/MSW ignition. Lee et al. [37] recommended pyrolysis synergy as the key to the success of MSW slow pyrolysis practise, that treat waste with maximum resource retrieval and lowest carbon emission. Yaman et al. [38] investigated the possibilities for GHG reductions and energy recovery from MSW in Dammam, Saudi Arabia. Also, they was explored, as well as the quantity of landfill gas created, the possibility for energy conversion, and the environmental consequences in terms of Greenhouse gas emission. Gupta et al. [39] described municipal solid waste incineration bottom ash (MIBA) from three Delhi incineration plants. MIBA from three MSWI plants has been characterized in order to determine whether it should be disposed of or reused. Das et al. [40] proposed various MSW management methods, distinct problems, and reasonable solutions for people involved in waste management, as well as a potential management strategy during and after the COVID-19 pandemic. Liu et al. [41] utilized a coupled fuzzy MCDM technique to locate landfills in Lanzhou, a semi-arid valley basin city in China, to optimize the regional decision-making approach. Mishra et al. [42] discussed solid waste management models and disposals for various sceneries. Ali et al. [43] investigate the new CIVPFS principle and its algebraic operational laws. Certain Einstein operational laws based on the t-norm and t-conorm are also developed using the CIVPFSs. Certain properties of soft multi-set topology with applications in MCDM were established by Riaz et al. [44]. Sahu et al. [45] proposed picture fuzzy sets and rough set-based approaches to assist students in selecting an appropriate subject and, consequently, to provide a better service or contribution to the community.

Multi-criteria group decision making (MCGDM) is a valuable research topic with extensive theoretical and practical backgrounds. It refers to the problem of identifying or ranking alternatives based on the opinions provided by multiple experts relating multiple criteria. Many scholars have been derived to the MCGDM problem, and numerous solutions have been proposed. Numerous researchers have thoroughly researched MCGDM under these methods, such as the TOPSIS [14,46], ELECTRE and VIKOR [47], MULTIMOORA [13], and the PROMETHEE [48] method. In recent years, the q-rung orthopair fuzzy set (q-ROFS) has received a lot of recognition and has been widely used in the decision-making field. The q-ROFSs have a greater ability to explain complexity and confusion in contexts with extreme degrees of uncertainty.

**Table 2:** ELECTRE model types in different forms of fuzzy sets

| Authors | Method | Problem description |
|---|---|---|
| Balali et al. [49] | ELECTRE III | To choose an acceptable structural system in the design of a building. |
| Hashemi et al. [50] | IVIF-ELECTRE III | To select best investment ventures. |
| Shen et al. [51] | IF-ELECTRE III | To evaluate the collateral risk of a financial company's partners. |
| Peng et al. [52] | ELECTRE III | To assess the cost of investing in energy supplies. |

Liu et al. [53] evaluated the q-rung orthopair fuzzy aggregation operators in MADM. One of the most well-known MCDM approaches addressing the problem of solid waste disposal is the ELECTRE III method. The proposed model expresses the concordance and discordance functions, as well as the optimum values of the ELECTRE III method's preference, indifference, and veto threshold parameters, in terms of IVq-ROFNs, which can be considered significant contributions of the ELECTRE III method to the MCGDM methodology. The ELECTRE model has many types, including ELECTRE I, ELECTRE II, ELECTRE III, ELECTRE IV, ELECTRE V, and so on. The ELECTRE III approach has been used to find fuzzy binary relations to represent mutual preferences and Table 2 provides a review of literature on the different ELECTRE model in various forms of fuzzy sets. Here, the study developed the fuzzy ELECTRE III with IVq-ROFS which aims to improve the SWM in India during the COVID-19 pandemic period. The suggested treatment technique helps to reduce the amount of waste in this critical situation. We have compared our proposed method with some MCDM models, also conducted a sensitivity analysis.

### *2.1 Motivation of the Study*

- In the existing literature, numerous researchers have worked on the application of MSW management in various types of MCDM methods. The purpose of this research paper is to create a novel assessment model for the solid waste disposal problem.
- For solid waste disposal treatment in an IVq-ROF environment, there have been no studies that have used the fuzzy ELECTRE III method. As a consequence, it is necessary to fill the research gap for solid waste disposal treatments.
- We developed this based on the expense, society, ecosystems, and technological aspects, to dispose both organic and inorganic solid wastes effectively using IVq-ROFN-ELECTRE III. The ELECTRE III model effectively responds to the MSW technique applicability requirements which promote us to research and develop our proposed version.
- This type of MCDM study is to identify appropriate techniques for reducing waste and unsanitary ecological disasters. During the pandemic, this type of waste disposal system will improve waste management.

### *2.2 Contribution of the Study*

The contribution of this study are as follows:

- Performs waste disposable treatment in terms of low management and operational costs, low level pollutions, more social benefits and less ecological harms, we present the IVq-ROFS-ELECTRE III method, which chooses the weight detection technique and deploys alternatives at an ambiguous situation.
- Linguistic scales for interval-valued q-rung orthopair fuzzy sets are defined from a decider perspective, furthermore IV-q-ROFSs is more adaptable and has a wider optimal solution than other fuzzy sets.
- Comparative analysis to validate the suitability of ELECTRE III method for our proposed organic and inorganic waste disposable problem with existing techniques such as TOPSIS, MULTIMOORA, and MABAC. Meanwhile, the sustainability also analysed and presented in the form of sensitivity analysis.

The paper further proceeds in Section 3 that discusses preliminaries, Section 4 presents the mathematical methods, Section 5 provides the numerical example is illustrated to show the efficiency of the proposed method and Section 6 presents comparison and sensitivity analysis. Finally, conclusion and future work are given in Section 7.

## 3 Preliminaries

**Definition 3.1** [5] Assume that $U$ be a non-empty fix set, then a q-ROFS $F$ on $U$ can be described as follows:

$$F = \{< u, (\theta_F(u), \phi_F(u)) > | u \in U\} \tag{1}$$

where $\theta_F(u) : U \to [0, 1]$ and $\phi_F(u) : U \to [0, 1]$ are represent the degree of membership and non-membership of $u$ to $F$, respectively, which satisfies $0 \le (\theta_F(u))^q + (\phi_F(u))^q \le 1, (q \ge 1)$. The indeterminacy degree is given as $\beta_F(u) = \sqrt[q]{(\theta_F(u))^q + (\phi_F(u))^q - ((\theta_F(u))^q)((\phi_F(u))^q)}$, $< \theta_F(u), \phi_F(u) >$ is called a q-ROFN, which is represented by $\gamma = (\theta_F, \phi_F)$ and shown in Fig. 1

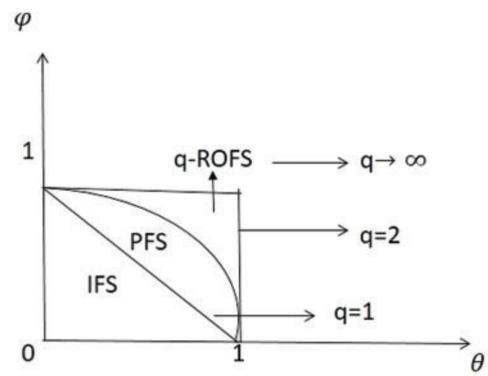



**Figure 1:** The relationship between IFS, PFS, and q-ROFS

**Definition 3.2** [6] Assume $U$ be a non-empty fixed set, an interval-valued q-rung orthopair fuzzy set (IVq-ROFS) $F$ on $U$ can be described as follows:

$$F = \{< u, ([\theta_F^L(u), \theta_F^U(u)], [\phi_F^L(u), \phi_F^U(u)]) > | u \in U\} \tag{2}$$

where $[\theta_F^L(u), \theta_F^U(u)]$ and $[\phi_F^L(u), \phi_F^U(u)]$ are represent the degree of membership and non-membership of $u$ to $F$, respectively, which satisfies $[\theta_F^L(u), \theta_F^U(u)] \subseteq [0, 1]$, $[\phi_F^L(u), \phi_F^U(u)] \subseteq [0, 1]$, and $0 \le (\theta_F^U(u))^q + (\phi_F^U(u))^q \le 1, (q \ge 1)$. The indeterminacy degree is given as

$$[\beta_F^L(u), \beta_F^U(u)] = [\sqrt[q]{1 - (\theta_F^U(u))^q - (\theta_F^U(u))^q}, \sqrt[q]{1 - (\phi_F^L(u))^q - (\phi_F^L(u))^q}]$$

$<[\theta_F^L(u), \theta_F^U(u)], [\phi_F^L(u), \phi_F^U(u)] >$ is called a IVq-ROFN, which is represented by $\gamma = ([\theta_F^L, \theta_F^U], [\phi_F^L, \phi_F^U])$.

**Definition 3.3** [6] Let $k = ([\theta_k^L, \theta_k^U], [\phi_k^U, \theta_k^U])$ be an IVq-ROFN, then the score function $S(k)$ and the accuracy function $A(k)$ are defined as below:

$$S(k) = \frac{1 + (\theta_k^U)^q - (\phi_k^U)^q + 1 + (\theta_k^L)^q - (\phi_k^L)^q}{4} \tag{3}$$

$$A(k) = \frac{(\theta_k^U)^q + (\theta_k^L)^q + (\phi_k^U)^q + (\phi_k^L)^q}{4} \tag{4}$$

**Definition 3.4** [6] Let $k_j = ([\theta_j^L, \theta_j^U], [\phi_j^L, \phi_j^U])$ be a list of IVq-ROFNs, then the interval-valued q-rung orthopair fuzzy weighted averaging (IVq-ROFWA) operator, that is IVq-ROFWA: $\Gamma^n \to \Gamma$ can be expressed as

$$IVq-ROFWA(k_1, k_2, \ldots, k_n) = \oplus_{j=1}^{n} w_j a_j \tag{5}$$

in which $\Gamma$ is the set of all IVq-ROFNs, $w = (w_1, w_2, \ldots, w_n)^T$ is the weight vector of $k_j (j = 1, 2, \ldots, n)$, such that $w_j \in [0, 1]$ and $\sum_{j=1}^{n} w_j = 1$.

**Definition 3.5** [54] Let $k_j = ([\theta_j^L, \theta_j^U], [\phi_j^L, \phi_j^U])$ be a list of IVq-ROFNs, then the interval-valued q-rung orthopair fuzzy weighted geometric (IVq-ROFWG) operator, that is IVq-ROFWG: $\Gamma^n \to \Gamma$ can be expressed as

$$IVq-ROFWG(k_1, k_2, \ldots, k_n) = \otimes_{j=1}^{n} w_j a_j \tag{6}$$

in which $\Gamma$ is the set of all IVq-ROFNs, $w = (w_1, w_2, \ldots, w_n)^T$ is the weight vector of $k_j (j = 1, 2, \ldots, n)$, such that $w_j \in [0, 1]$ and $\sum_{j=1}^{n} w_j = 1$.

We can find the particular form of the aggregation result, which is given in below theorem.

**Theorem 3.1** [6] Let $k_j = ([\theta_j^L, \theta_j^U], [\phi_j^L, \phi_j^U]) (j = 1, 2, \ldots, n)$ be a list of IV-ROFNs, $w = (w_1, w_2, \ldots, w_n)^T$ is the weight vector of $k_j$, such that $w_j \in [0, 1]$ and $\sum_{j=1}^{n} w_j = 1$. Then, their aggregated value by Definition 3.4 is still a IVq-ROFN, and has

$$\begin{aligned} IVq-ROFWA(k_1, k_2, \ldots, k_n) = \Bigg\langle & \left[ \left( 1 - \prod_{j=1}^{n} (1 - (\theta_j^L)^q)^{w_j} \right)^{\frac{1}{q}}, \left( 1 - \prod_{j=1}^{n} (1 - (\theta_j^U)^q)^{w_j} \right)^{\frac{1}{q}} \right], \\ & \left[ \prod_{j=1}^{n} (\phi_j^L)^{w_j}, \prod_{j=1}^{n} (\phi_j^U)^{w_j} \right] \Bigg\rangle \end{aligned} \tag{7}$$

**Theorem 3.2** [6,54] Let $k_j = ([\theta_j^L, \theta_j^U], [\phi_j^L, \phi_j^U]) (j = 1, 2, \ldots, n)$ be a list of IV-ROFNs, $w = (w_1, w_2, \ldots, w_n)^T$ is the weight vector of $k_j$, such that $w_j \in [0, 1]$ and $\sum_{j=1}^{n} w_j = 1$. Then, their aggregated value by Definition 3.5 is still a IVq-ROFN, and has

$$\begin{aligned} IVq-ROFWG(k_1, k_2, \ldots, k_n) = \Bigg\langle & \left[ \prod_{j=1}^{n} (\theta_j^L)^{w_j}, \prod_{j=1}^{n} (\theta_j^U)^{w_j} \right], \\ & \left[ \left( 1 - \prod_{j=1}^{n} (1 - (\phi_j^L)^q)^{w_j} \right)^{\frac{1}{q}}, \left( 1 - \prod_{j=1}^{n} (1 - (\phi_j^U)^q)^{w_j} \right)^{\frac{1}{q}} \right] \Bigg\rangle \end{aligned} \tag{8}$$

Theorems 3.1 and 3.2 can be proved by the mathematical induction, which is not repeated here.

**Definition 3.6** [55] Let $k_1 = ([\theta_1, \theta_1], [\phi_1, \phi_1])$ and $k_2 = ([\theta_2, \theta_2], [\phi_2, \phi_2])$ are two IVq-ROFNs, then we can obtain the interval-valued q-rung orthopair fuzzy normalized hamming distance (IVq-ROFNHD) is given as follows:

$$\begin{aligned} d_q - IVq - ROFNHD(k_1, k_2) = \frac{1}{4} \Big( & |(\theta_1^L)^q - (\theta_2^L)^q| + |(\theta_1^U)^q - (\theta_2^U)^q| + \\ & |(\phi_1^L)^q - (\phi_2^L)^q| + |(\phi_1^U)^q - (\phi_2^U)^q| + \\ & |(1 - (\theta_1^L)^q - (\phi_1^L)^q)^{\frac{1}{q}} - (1 - (\theta_2^L)^q - (\phi_2^L)^q)^{\frac{1}{q}}| + \\ & |(1 - (\theta_1^U)^q - (\phi_1^U)^q)^{\frac{1}{q}} - (1 - (\theta_2^U)^q - (\phi_2^U)^q)^{\frac{1}{q}}| \Big) \end{aligned} \tag{9}$$

# 4 Mathematical Methods

## *4.1 The Conventional ELECTRE III Model*

Let $O = (o_1, o_2, o_3, \ldots, o_u)$ represent a finite number of alternatives and $P = (p_1, p_2, p_3, \ldots, p_v)$ represent a finite number of criteria for an MCDM problem; $p_j(o_j)$ denotes the performance of the alternative $o_j \in O$ for the criteria $p_j$. The greater or lessor the criterion $p_j(o_j)$, depending on whether the focus is to maximize or minimize it, the higher the alternative meets the above criterion. As a result, the vector $p(o) = (p_1(o), p_2(o), \ldots, p_v(o))$ will represent the multi-criteria assessment of the alternative $o_j \in O$.

The ELECTRE III model's assessment process include the formation of a threshold function, the disclosure of concordance and discordance indices, the determination of the credibility degree, and the ranking of the alternatives. The ELECTRE III procedure and computations are shown below.

**Step 1:** The concordance index $C(o_1, o_2)$ is calculated for every pair of alternatives:

$$CCM(o_1, o_2) = \frac{\sum_{j=1}^{v} w_j \ CCM_j(o_1, o_2)}{\sum_{j=1}^{v} w_j}$$

where $CCM_i(o_1, o_2)$ is the outranking degree of the alternative $o_1$ and $o_2$ under the criteria $i$, and

$$CCM_i(o_1, o_2) = \begin{cases} 0 \quad if \quad p_i(o_2) - p_i(o_1) > F_i(p_i(o_1)) \\ 1 \quad if \quad p_i(o_2) - p_i(o_1) \le T_i(p_i(o_1)) \\ \frac{F_i + p_i(o_1) - p_i(o_2)}{F_i - T_i} \qquad otherwise \end{cases}$$

Thus, $0 \le CCM_i(o_1, o_2) \le 1$. The veto threshold $M_i(p_i(o_2))$ is described for each criterion $i$ is defined in reference [50]. Where $F$ represents a strong preference, $T$ represents a weak preference, $M$ represents indifference.

**Step 2:** The discordance index $DCM(o_1, o_2)$ for each criterion is described below:

$$DCM_i(o_1, o_2) = \begin{cases} 0 \quad if \quad p_i(o_2) - p_i(o_1) \le F_i(p_i(o_1)) \\ 1 \quad if \quad p_i(o_2) - p_i(o_1) > M_i(p_i(o_1)) \\ \frac{p_i(o_2) - p_i(o_1) - F_i}{M_i - F_i} \qquad otherwise \end{cases}$$

Thus, $0 \leq DCM_j(o_1, o_2) \leq 1$.

**Step 3:** Finally, the degree of outranking is defined by $S(o_1, o_2)$:

$$S_i(o_1, o_2) = \begin{cases} CCM(o_1, o_2) \quad if \quad DCM_j(o_1, o_2) \leq CCM(o_1, o_2) \forall j \in J \\ CCM(o_1, o_2) \times \prod_{j \in J} \frac{1 - DCM_j(o_1, o_2)}{1 - CCM_j(o_1, o_2)} \qquad otherwise \end{cases}$$

where $J(o_1, o_2)$ is the set of criteria for which $DCM(o_1, o_2) > CCM(o_1, o_2)$.

**Step 4:** To calculate the complete ranking of the alternatives and the concordance credibility degree, the discordance credibility degree and the net credibility degree are obtained as:

- The concordance credibility value is described by

  $$\chi^+(o_i) = \sum_{\forall u \in (i=1,2,\ldots,u)} S(o_1, o_2)$$

  The concordance credibility is a proportion of $O_i$'s outranking character.
- The discordance credibility value is described by

  $$\chi^-(o_i) = \sum_{\forall u \in (i=1,2,\ldots,u)} S(o_1, o_2)$$

  s The discordance credibility is a portrays of $O_i$'s outranking character.
- The net credibility value is described by

  $\chi(o_i) = \chi^+(o_i) - \chi^-(o_i), \quad \forall \quad o_i$

The net credibility degree describes the value system, with a higher value reflecting the attractiveness of the alternative $o_i$. Then, using the net credibility degree, all of the alternatives can be completely ranked.

### *4.2 Proposed Method*

Here, we expand the ELECTRE III method with IVq-ROFSs. Consider a $u$ alternatives $\{o_1, o_2, \ldots, o_u\}$, $v$ criteria $\{p_1, p_2, \ldots, p_v\}$ and $\beta$ experts $\{e_1, e_2, \ldots, e_\beta\}$ with weighting vector be $\{w_1, w_2, \ldots, w_\beta\}$, then the procedure of group decision making by IVq-ROFN-ELECTRE III model is described in the following steps, as shown in Fig. 2.

**Step 1: Obtain the significance of each expert**

It is necessary to assess the significance of each expert in the final judgement. Let $\gamma = \{\gamma_1, \gamma_2, \ldots, \gamma_\beta\}$ is the decision-makers significant vector, where $\gamma_e \geq 0, e = 1, 2, \ldots, \beta$ is the importance of $\beta$ th experts and $\sum_{e=1}^{\beta} \gamma_e = 1$. If decision makers has equally importance, then $\gamma_1 = \gamma_2 = \ldots = \gamma_\beta = \frac{1}{\beta}$.

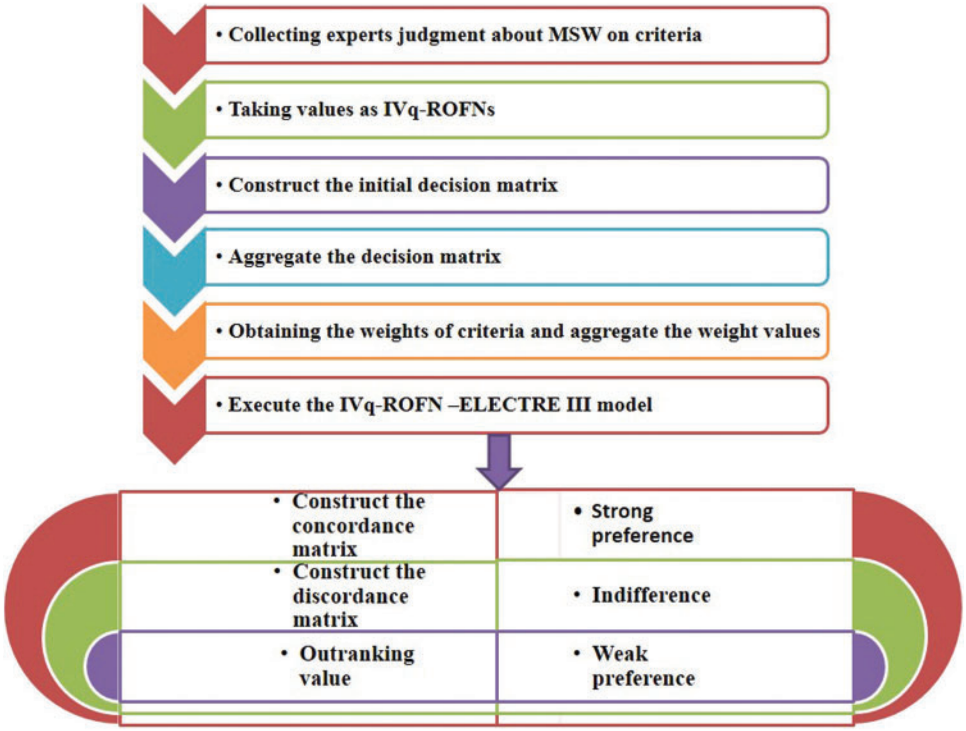



**Figure 2:** Pictorial representation of the proposed method

**Step 2: Construct the matrix and aggregate the experts matrix**

Here, experts express their point of view, and assess the alternatives using the linguistic scale seen in Table 3 which is expressed by the IVq-ROFNs. Let $r_{ij}^{\beta}, i = 1, 2, 3, \ldots, u,\ j = 1, 2, \ldots, v$ is the $\beta$ the decision makers assess the raking of alternatives and experts matrix is described as follows:

$$\tilde{R}^{\beta} = \begin{array}{c} \\ O_1 \\ O_2 \\ \vdots \\ O_s \end{array} \begin{array}{c} \begin{array}{cccc} P_1 & P_2 & \cdots & P_t \end{array} \\ \begin{pmatrix} ([(\theta_{11}^{\beta})^L, (\theta_{11}^{\beta})^U][(\phi_{11}^{\beta})^L, (\phi_{11}^{\beta})^U]) & ([(\theta_{12}^{\beta})^L, (\theta_{12}^{\beta})^U][(\phi_{12}^{\beta})^L, (\phi_{12}^{\beta})^U]) & \cdots & ([(\theta_{1t}^{\beta})^L, (\theta_{1t}^{\beta})^U][(\phi_{1t}^{\beta})^L, (\phi_{1t}^{\beta})^U]) \\ ([(\theta_{21}^{\beta})^L, (\theta_{21}^{\beta})^U][(\phi_{21}^{\beta})^L, (\phi_{21}^{\beta})^U]) & ([(\theta_{22}^{\beta})^L, (\theta_{22}^{\beta})^U][(\phi_{22}^{\beta})^L, (\phi_{22}^{\beta})^U]) & \cdots & ([(\theta_{2t}^{\beta})^L, (\theta_{2t}^{\beta})^U][(\phi_{2t}^{\beta})^L, (\phi_{2t}^{\beta})^U]) \\ \vdots & \vdots & \ddots & \vdots \\ ([(\theta_{s1}^{\beta})^L, (\theta_{s1}^{\beta})^U][(\phi_{s1}^{\beta})^L, (\phi_{s1}^{\beta})^U]) & ([(\theta_{s2}^{\beta})^L, (\theta_{s2}^{\beta})^U][(\phi_{s2}^{\beta})^L, (\phi_{s2}^{\beta})^U]) & \cdots & ([(\theta_{st}^{\beta})^L, (\theta_{st}^{\beta})^U][(\phi_{st}^{\beta})^L, (\phi_{st}^{\beta})^U]) \end{pmatrix} \end{array} \tag{10}$$

The aggregate the decision maker's matrices as follows:

$$IVq - ROFWA(e_1, e_2, \ldots, e_n) = \left\langle \left[ \left( 1 - \prod_{j=1}^{n} (1 - (\theta_j^L)^q)^{w_j} \right)^{\frac{1}{q}}, \left( 1 - \prod_{j=1}^{n} (1 - (\theta_j^U)^q)^{w_j} \right)^{\frac{1}{q}} \right], \left[ \prod_{j=1}^{n} (\phi_j^L)^{w_j}, \prod_{j=1}^{n} (\phi_j^U)^{w_j} \right] \right\rangle \tag{11}$$

The aggregated decision matrix R is

$$\tilde{R} = \begin{array}{c} \\ o_1 \\ o_2 \\ \vdots \\ o_s \end{array} \begin{array}{cccc} p_1 & p_2 & \cdots & p_t \end{array} \left( \begin{array}{cccc} ([(\theta_{11})^L,(\theta_{11})^U][(\phi_{11})^L,(\phi_{11})^U]) & ([(\theta_{12})^L,(\theta_{12})^U][(\phi_{12})^L,(\phi_{12})^U]) & \cdots & ([(\theta_{1t})^L,(\theta_{1t})^U][(\phi_{1t})^L,(\phi_{1t})^U]) \\ ([(\theta_{21})^L,(\theta_{21})^U][(\phi_{21})^L,(\phi_{21})^U]) & ([(\theta_{22})^L,(\theta_{22})^U][(\phi_{22})^L,(\phi_{22})^U]) & \cdots & ([(\theta_{2t})^L,(\theta_{2t})^U][(\phi_{2t})^L,(\phi_{2t})^U]) \\ \vdots & \vdots & \ddots & \vdots \\ ([(\theta_{s1})^L,(\theta_{s1})^U][(\phi_{s1})^L,(\phi_{s1})^U]) & ([(\theta_{s2})^L,(\theta_{s2})^U][(\phi_{s2})^L,(\phi_{s2})^U]) & \cdots & ([(\theta_{st})^L,(\theta_{st})^U][(\phi_{st})^L,(\phi_{st})^U]) \end{array} \right) \tag{12}$$

**Table 3:** Fuzzy linguistic scale for rating the alternatives with respect to selected criteria

| Linguistic term | Fuzzy number |
|---|---|
| Worst (W) | ([0.14, 0.15], [0.94, 0.95]) |
| Very Poor (VP) | ([0.34, 0.35], [0.74, 0.75]) |
| Poor (P) | ([0.44, 0.45], [0.64, 0.65]) |
| Fair (F) | ([0.54, 0.55], [0.55, 0.56]) |
| Good (G) | ([0.64, 0.65], [0.44, 0.45]) |
| Very Good (VG) | ([0.74, 0.75], [0.34, 0.35]) |
| Extremely Good (EG) | ([0.94, 0.95], [0.14, 0.15]) |

**Step 3: Calculate the criterion weights**

Let $w_j^\beta = ([\theta_{Lj}^\beta, \theta_{Uj}^\beta], [\phi_{Lj}^\beta, \phi_{Uj}^\beta])$ is the $\beta$th experts decision about the significance of the criterion using the linguistic scale in Table 4. Then, the aggregated weights of criteria are obtained by calculating the IVq-ROFWA operator using Eq. (11) and weights of criterion is obtained by experts.

**Step 4: Construct the concordance matrix**

For concordance matrix $CCM(o_1, o_2)$, we should first find the thresholds, which are $F, T, M$ represents the strong preference, weak preference, and indifference respectively and the CCM is calculated by Eq. (13).

$$CCM(o_1, o_2) = \frac{\sum_{j=1}^{v} w_j \ CCM_j(o_1, o_2)}{\sum_{j=1}^{v} w_j} \tag{13}$$

where

$$CCM_i(o_1, o_2) = \begin{cases} 0 \quad if \quad S(o_2) - S(o_1) > S(F_i) \\ 1 \quad if \quad S(o_2) - S(o_1) \leq S(T_i) \\ \frac{S(F_i)+S(o_1)-S(o_2)}{S(F_i)-S(T_i)} \qquad otherwise \end{cases}$$

where $S(o_1), S(o_2), S(F_i)$ and $S(T_i)$ are calculated by Eq. (3).

**Step 5: Construct the discordance matrix**

Obtain the discordance matrix $DCM(o_1, o_2)$. The DCM is described in given Eq. (14).

$$CCM_i(o_1, o_2) = \begin{cases} 0 \quad if \quad S(o_2) - S(o_1) \leq S(F_i) \\ 1 \quad if \quad S(o_2) - S(o_1) > S(T_i) \\ \frac{S(o_2) - S(o_1) - S(F_i)}{S(M_i) - S(F_i)} \qquad otherwise \end{cases} \tag{14}$$

where, $0 \leq DCM_j(o_1, o_2) \leq 1$.

**Step 6:** Calculate the outranking degree $S(o_1, o_2)$ is in (15)

$$S(o_1, o_2) = \begin{cases} CCM(o_1, o_2) \qquad if \quad DCM(o_1, o_2) \leq CCM(o_1, o_2) \\ CCM(o_1, o_2) \times \prod_{j \in J} \frac{1 - DCM_j(o_1, o_2)}{1 - CCM_j(o_1, o_2)} \qquad otherwise \end{cases} \tag{15}$$

**Step 7:** Finally, ranting the alternatives based on concordance credibility, the discordance credibility, and the net credibility values.

- The concordance credibility value is described by

$$\chi^+(o_i) = \sum_{\forall u \in (i = 1, 2, \ldots, u)} S(o_1, o_2) \tag{16}$$

The concordance credibility is a proportion of $O_i$'s outranking character.

- The discordance credibility value is described by

$$\chi^-(o_i) = \sum_{\forall u \in (i = 1, 2, \ldots, u)} S(o_1, o_2) \tag{17}$$

The discordance credibility is a portrays of $O_i$'s outranking character.

- The net credibility value is described by

$$\chi(o_i) = \chi^+(o_i) - \chi^-(o_i), \quad \forall \quad o_i \tag{18}$$

The net credibility value reflects the worth capability, with a higher worth indicating a huge engaging quality of $o_i$. Both $o_i$'s can be fully placed based on net credibility.

## 5 Numerical Example

The world is facing solid waste management as an important issue in the current situation, with household and health-care solid waste amounts increasing during this lock-down period. The spread of COVID-19 altered people's lifestyles, resulting in an increase in waste and difficulties in disposing of solid waste. We make it necessary to improve waste disposal in a responsible manner. As a result, several attempts have been made to find waste disposal solutions that reduce waste while also reducing the risk of COVID-19 transmission through solid waste. In India, SW (organic & inorganic waste) disposal is at a crucial level of development. Hence the facility to dispose the wastes should be improved. It is estimated that over 90 percentage of the waste in India is dumped in an unsatisfactory manner. Properly planned management of waste improves public health and protects critical natural resources such as surface water, soil fertility, and air quality. Interactions with SW processes at open dump areas are at serious risk in developing countries. Waste administrators are specifically affected by the handling of these solid wastes and by workplace risks or illnesses and infections transmitted to their employees. There are a variety of critical public health implications of SW. It has adverse consequences directly or implicitly on various groups of individuals, such as waste collectors, municipal employees, and waste disposal workers. Skin inflammation, typhoid fever, cholera, asthma, cancer, vomiting, food poisoning, etc., are diseases related to improper disposal of waste.

The most popular waste management strategies, such as dumping at open sites and traditional incineration, are practiced in many countries. Such approaches are rather unhygienic and pose a serious challenge to public health and the ecosystems. The design and operation of sustainable and robust waste management schemes includes the collection, transport and recycling of solid waste. SW contains organic and inorganic materials, which are shown in Fig. 3. **Organic waste:** Biologically generated waste (which was once alive or was part of an organism). **Inorganic waste:** Non-biological waste is a form of waste that does not have a biological basis (industrial origin or any non-natural process). Organic waste application has long been recognized as valuable to soil fertility, erection, water preservation, and buffering skill. The majority of solid waste is organic, with just a small volume of inorganic waste and no hazardous waste (SBMG, 2015). Here, we consider the four alternatives to dispose organic and inorganic waste and explained as follows [1,2].

**Recycling& Sanitary Landfills (RC & SL):** Recycling is a method by which products are stored, handled, and re-manufactured that is otherwise intended for disposal. Recycling diverts a large fraction of metropolitan, institutional and industry waste from recycling, thus saving precious environmental resources, reducing the effect on the environment and the cost of waste control on public authorities. Sanitary landfills are structures planned and built for the ultimate disposal of solid waste on land to reduce environmental impacts. A modern landscape that meets these requirements is a complex facility with various equipment to reduce environmental impacts. Non-useable, non-recyclable, non-biodegradable, non-combustible and non-reactive inert waste to go to sanitary landfills and pre-processing rejects and contaminants from waste processing facilities are permitted in sanitary landfills. The best landfill site is the one dispose method which minimizes the negative effects on the society and ecosystem, as well as has the greatest economic and engineering performance.

**Anaerobic Digestion:** Anaerobic digestion (AD) is a mechanism in which, in the absence of oxygen, organic matter is converted into biogas and digested. The longevity of MSW's AD is based on multiple factors. In order to be sustainable, the sum of benefits needs to outweigh the effects of the AD operation (pre-treatment, digestion process and post-treatment) as well as logistics. As a result of the evolving issue of waste management and energy protection, AD has gained expanded research attention and implementation. It provides numerous environmental advantages, including green energy generation, agricultural waste collection, and environmental conservation and GHG emission reductions. The solids developed after the AD phase can be used as soil modifications that are good for the environment. In addition to technological and economic treatment evaluations, adding environmental impact assessments would enable biogas processing to be ecosystem friendly.

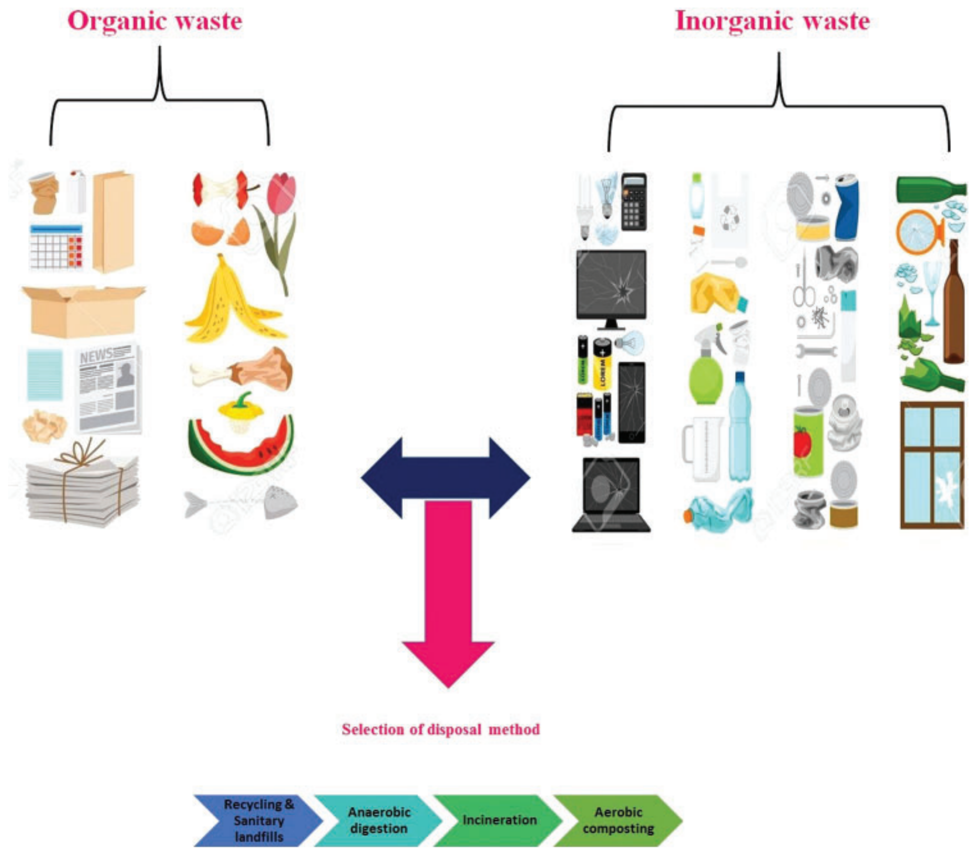



**Figure 3:** Solid waste disposal problem

**Incineration:** An incineration is a form of waste disposal that involves the burning of waste in the presence of oxygen at extremely high temperatures, resulting in the creation of ash, flue gas, and heat. Besides the separated fraction of high calorific waste, it is feasible for unprocessed or minimally processed refuse. Incineration is an alternative to be explored only when adequate resource recycling and reuse systems have been introduced or when other viable production solutions are not possible and the availability of land is a concern.

**Aerobic Composting:** Biologically, composting is a regulated aerobic process of "digesting" the SW can be recycled for plant nutrients, stabilization, soil in the remediation process, or soil alteration for low soil regeneration. Depending on the feasibility of implementation, compost production can be carried out at a decentralized level or a centralized level. Both processes require substantial pre-processing, and it is possible to compost only segregated organic matter. Home composting, bin composting, box composting, vermicomposting, in-vessel composting are the decentralized level, and windrow composting, aerated static pile, in-vessel composting are centralized level.

The proposed methodology is used in this section to assess the disposal method for organic and inorganic waste. The best method of disposal that has the least ecological impact is obtained and is useful for all societal requirements, to this end we have chosen eight criteria to evaluate the four alternatives, which are given as follows:

- Cost ($P_1$): There are various cost problems based on the type of disposal treatment and technology.
- Healthy and safety ($P_2$): The safety of people's health is the most important criterion in waste management. Solid waste disposal treatments ensure that workers personal safety are protected by proper management, treatment, processing, and disposal procedures.
- Air pollution ($P_3$): Some waste disposal pollutes the environment because chemicals are used to dispose of some waste.
- Noise pollution ($P_4$): The unpleasant, irritating sound made when waste is disposed of, which annoys both workers and society. Diseases are also caused by it.
- Soil and water pollution ($P_5$): When waste disposal treatment is implemented, it reduces the soil and water, have to improve the quality of the soil and water.
- Workers ($P_6$): Employees who are responsible for waste disposal and the operation of the solid waste management infrastructure framework.
- Technical efficiency and feasibility ($P_7$): Sufficient technologies need to operates the disposal methods for wastes.
- Land requirement and equipment facilities ($P_8$): Land and equipment are required to properly dispose of waste.

Here, we consider three decision-makers to evaluate the alternatives. Then, the alternatives are Recycling & Sanitary Landfills ($O_1$), Anaerobic Digestion ($O_2$), Incineration ($O_3$), and Aerobic Composting ($O_4$). The selected alternatives and criterion are shown in Fig. 4.

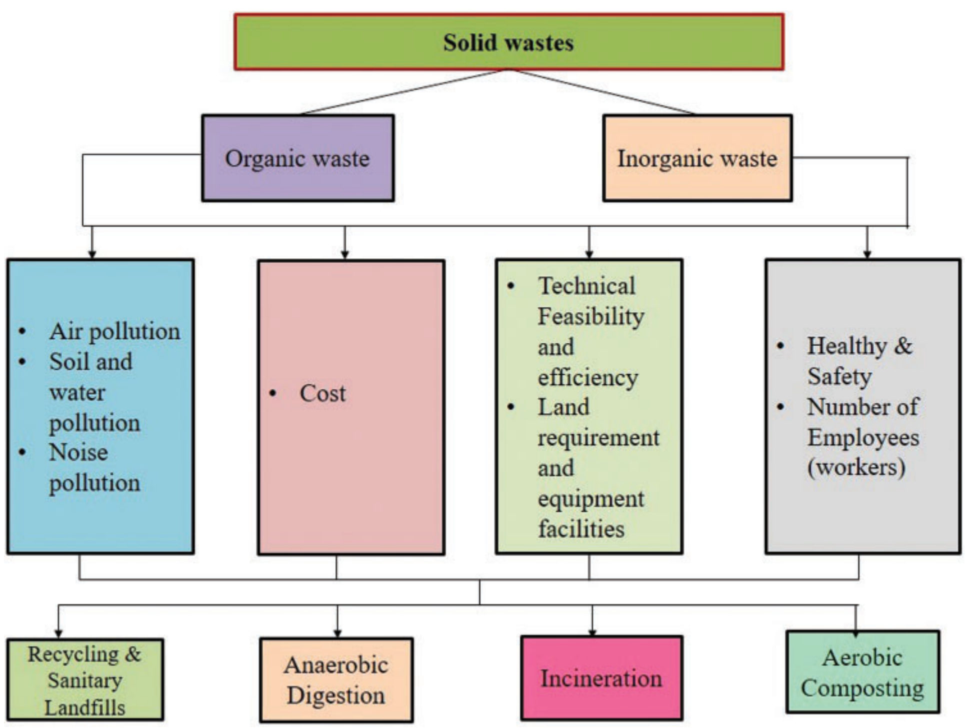



**Figure 4:** Organic & inorganic waste disposal method

### *5.1 Organic Waste*

Materials that are derived from living beings produce organic waste. The various forms of organic waste includes industries, municipal, waste water and food waste. Agricultural waste, food-soiled paper, food waste, non-hazardous wood waste, and landscaping are examples of organic waste. Food waste is mostly disposed in landfills or incinerators alongside other waste, but because it is biodegradable, some organic waste is ideal for composting and soil application. Organic content that can be broken into carbon dioxide, nitrogen, or basic organic compounds is biodegradable waste. Here, the decision makers evaluate the organic waste under the criteria which is represented as an IVq-ROFSs. The linguistic scale can be used to assessment alternatives that can assist experts to clearly express their evidence and viewpoints, which is shown in Tables 3 and 4. We are now analyzing organic waste using the proposed method.

**Table 4:** Fuzzy linguistic scale is used to define the importance of criteria

| Linguistic term | Fuzzy number |
|---|---|
| Very Unimportant (VU) | ([0.14, 0.15], [0.94, 0.95]) |
| Unimportant (U) | ([0.34, 0.35], [0.74, 0.75]) |
| Medium (M) | ([0.54, 0.55], [0.55, 0.56]) |
| Important (I) | ([0.74, 0.75], [0.34, 0.35]) |
| Very Important (VI) | ([0.94, 0.95], [0.14, 0.15]) |

The following alternatives are considered for evaluation: $O_1$-Recycling & Sanitary Landfills (RC & SL), $O_2$-Anaerobic Digestion, $O_3$-Incineration and $O_4$-Aerobic Composting based on the eight criteria by three experts $e_\beta$ and the initial decision matrix for experts with q = 4, as shown in Tables 5–7.

**Table 5:** Decision matrix with linguistic variables for organic solid waste-$DM_1$

| | $P_1$ | $P_2$ | $P_3$ | $P_4$ | $P_5$ | $P_6$ | $P_7$ | $P_8$ |
|---|---|---|---|---|---|---|---|---|
| $O_1$ | VG | F | F | F | W | F | VG | P |
| $O_2$ | VG | VG | VG | EG | EG | G | G | F |
| $O_3$ | G | W | VP | F | W | P | G | VP |
| $O_4$ | VG | G | VG | G | F | G | G | F |

**Table 6:** Decision matrix with linguistic variables for organic solid waste-$DM_2$

| | $P_1$ | $P_2$ | $P_3$ | $P_4$ | $P_5$ | $P_6$ | $P_7$ | $P_8$ |
|---|---|---|---|---|---|---|---|---|
| $O_1$ | G | G | VG | F | W | P | P | P |
| $O_2$ | G | VG | G | G | F | F | P | F |
| $O_3$ | F | P | W | F | VP | P | VP | VP |
| $O_4$ | EG | VG | VG | VG | VG | G | G | VG |

**Table 7:** Decision matrix with linguistic variables for organic solid waste-$DM_3$

| | $P_1$ | $P_2$ | $P_3$ | $P_4$ | $P_5$ | $P_6$ | $P_7$ | $P_8$ |
|---|---|---|---|---|---|---|---|---|
| $O_1$ | G | G | VG | VG | W | P | G | VP |
| | $P_1$ | $P_2$ | $P_3$ | $P_4$ | $P_5$ | $P_6$ | $P_7$ | $P_8$ |
| $O_2$ | VG | VG | EG | VG | EG | G | VG | G |
| $O_3$ | F | W | W | P | W | VP | F | P |
| $O_4$ | VG | G | F | F | G | P | G | F |

**Step 1:** Obtain the significance of each expert. The importance of the weight vector for each expert is $\gamma = (0.45, 0.25, 0.30)$.

**Step 2:** Now, the construct the initial matrix using the linguistic scale, decision makers evaluate the organic waste disposal under the selected criterion and the aggregation of the expert's matrix is shown in Table 8.

**Table 8:** The aggregated matrix for organic solid waste

| | $P_1$ | $P_2$ | $P_3$ | $P_4$ | $P_5$ | $P_6$ | $P_7$ | $P_8$ |
|---|---|---|---|---|---|---|---|---|
| $O_1$ | ([0.6926, 0.7026], [0.3918, 0.4019]) | ([0.6022, 0.6122], [0.4865, 0.4965]) | ([0.6772, 0.6872], [0.4222, 0.4324]) | ([0.6281, 0.6381], [0.4761, 0.4864]) | ([0.1400, 0.1500], [0.9400, 0.9500]) | ([0.4932, 0.5031], [0.5978, 0.6078]) | ([0.6700, 0.6800], [0.4303, 0.4406]) | ([0.4172, 0.4271], [0.6685, 0.6785]) |
| $O_2$ | ([0.7201, 0.7302], [0.3626, 0.3727]) | ([0.7400, 0.7500], [0.3400, 0.3500]) | ([0.8341, 0.8476], [0.2779, 0.2890]) | ([0.8675, 0.8809], [0.2433, 0.2545]) | ([0.9103, 0.9224], [0.1971, 0.2085]) | ([0.6201, 0.6300], [0.4652, 0.4753]) | ([0.6519, 0.6619], [0.4472, 0.4575]) | ([0.5768, 0.5868], [0.5144, 0.5244]) |
| $O_3$ | ([0.5925, 0.6025], [0.4975, 0.5075]) | ([0.3146, 0.3223], [0.8539, 0.8640]) | ([0.2811, 0.2898], [0.8441, 0.8541]) | ([0.5162, 0.5262], [0.5756, 0.5856]) | ([0.2457, 0.2538], [0.8854, 0.8955]) | ([0.4172, 0.4271], [0.6685, 0.6785]) | ([0.5713, 0.5811], [0.5358, 0.5460]) | ([0.3791, 0.3889], [0.7085, 0.7185]) |
| $O_4$ | ([0.8307, 0.8437], [0.2724, 0.2832]) | ([0.6712, 0.6813], [0.4125, 0.4226]) | ([0.7009, 0.7110], [0.3928, 0.4030]) | ([0.6513, 0.6614], [0.4411, 0.4513]) | ([0.6404, 0.6505], [0.4561, 0.4663]) | ([0.6012, 0.6111], [0.4923, 0.5025]) | ([0.6400, 0.6500], [0.4400, 0.4500]) | ([0.6163, 0.6263], [0.4877, 0.4979]) |

**Step 3:** The significance of each criteria by experts judgment is shown in Table 9. Then, using the IVq-ROFWA aggregation operator we can find the weight of the criteria's.

**Table 9:** The weight matrix for criteria of decision makers

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| $DM_1$ | M | VI | I | M | M | U | M | VI |
| $DM_2$ | U | I | M | M | M | VU | I | I |
| $DM_3$ | M | I | VI | U | M | M | M | M |

Now, the weight of the criterion are calculated using Eq. (11),

$w_1 = ([0.5099, 0.5197], [0.5924, 0.6024]), w_2 = ([0.8745, 0.8873], [0.2281, 0.2390])$

$w_3 = ([0.8287, 0.8425], [0.2938, 0.3053]), w_4 = ([0.5032, 0.5129], [0.6012, 0.6113])$

$w_5 = ([0.5400, 0.5500], [0.5500, 0.5600]), w_6 = ([0.4239, 0.4328], [0.7187, 0.7289])$

$w_7 = ([0.6163, 0.6263], [0.4877, 0.4979]), w_8 = ([0.8612, 0.8750], [0.2635, 0.2752])$

**Step 4:** For concordance matrix, the thresholds for alternatives are construct and which is shown in Table 10.

**Table 10:** Threshold values for alternative

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| $DM_1$ | G | F | P | F | G | W | P | P |
| $DM_2$ | F | VG | G | P | VG | P | F | G |
| $DM_3$ | W | P | VP | G | F | F | VP | F |

To determine the CCM, it is need to find the $S(O_j)$ and $S(w_j)$, as given in Table 11.

**Table 11:** Results of the alternatives and thresholds for organic solid waste

| | $P_1$ | $P_2$ | $P_3$ | $P_4$ | $P_5$ | $P_6$ | $P_7$ | $P_8$ |
|---|---|---|---|---|---|---|---|---|
| $O_1$ | 0.6060 | 0.5388 | 0.5916 | 0.5535 | 0.1014 | 0.4646 | 0.5858 | 0.4130 |
| $O_2$ | 0.6292 | 0.6470 | 0.7468 | 0.7902 | 0.8518 | 0.5519 | 0.5727 | 0.5209 |
| $O_3$ | 0.5319 | 0.2329 | 0.2434 | 0.4801 | 0.1875 | 0.4130 | 0.5123 | 0.3813 |
| $O_4$ | 0.7427 | 0.5894 | 0.6117 | 0.5730 | 0.5642 | 0.5369 | 0.5669 | 0.5450 |
| $T$ | 0.1014 | 0.3530 | 0.4331 | 0.1014 | 0.4967 | 0.1014 | 0.4331 | 0.4331 |
| $F$ | 0.4967 | 0.5669 | 0.3530 | 0.4331 | 0.1014 | 0.4331 | 0.3530 | 0.1014 |
| $M$ | 0.5669 | 0.4967 | 0.5669 | 0.6470 | 0.4331 | 0.4967 | 0.4967 | 0.4967 |

Now, the CCM is determined base on the comparison of the alternatives using Eq. (13), the results shown in Table 12.

**Table 12:** The concordance matrix for organic solid waste

| | $O_1$ | $O_2$ | $O_3$ | $O_4$ |
|---|---|---|---|---|
| $O_1$ | 1 | 0.6862 | 1 | 0.8148 |
| $O_2$ | 1 | 1 | 1 | 0.9969 |
| $O_3$ | 1 | 0.4481 | 1 | 0.6064 |
| $O_4$ | 1 | 0.9090 | 1 | 1 |

**Step 5:** The discordance matrix is obtained using (14) and the results are given in Table 13.

**Table 13:** The discordance matrix for organic solid waste

| | $P_1$ | | | | $P_2$ | | | | $P_3$ | | | | $P_4$ | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $O_1$ | $O_2$ | $O_3$ | $O_4$ | $O_1$ | $O_2$ | $O_3$ | $O_4$ | $O_1$ | $O_2$ | $O_3$ | $O_4$ | $O_1$ | $O_2$ | $O_3$ | $O_4$ |
| $O_1$ | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| $O_2$ | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 |
| $O_3$ | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 0.7031 | 0 | 0 | 1 | 0 |
| $O_4$ | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 |

(Continued)

**Table 13:** (continued)

| | $P_5$ | | | | $P_6$ | | | | $P_7$ | | | | $P_8$ | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $O_1$ | $O_2$ | $O_3$ | $O_4$ | $O_1$ | $O_2$ | $O_3$ | $O_4$ | $O_1$ | $O_2$ | $O_3$ | $O_4$ | $O_1$ | $O_2$ | $O_3$ | $O_4$ |
| $O_1$ | 1 | 1.9565 | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0.0164 | 0 | 0.0774 |
| $O_2$ | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 |
| $O_3$ | 0 | 1 | 1 | 0.8299 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0.0966 | 1 | 0.1576 |
| $O_4$ | 0 | 0.5613 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 |

**Step 6:** Then, the comparison between the CCM and DCM are calculated using Eq. (15) and the credibility matrix is given in Table 14.

**Table 14:** The credibility matrix for organic solid waste

| | $O_1$ | $O_2$ | $O_3$ | $O_4$ |
|---|---|---|---|---|
| $O_1$ | 1 | 0 | 1 | 0 |
| $O_2$ | 1 | 1 | 1 | 0.9969 |
| $O_3$ | 1 | 0 | 1 | 0 |
| $O_4$ | 1 | 0 | 1 | 1 |

**Step 7:** Finally, according to the Eqs. (16)–(18), the ranking results are obtained and shown in Table 15 and Fig. 5.

**Table 15:** The final ranking values for organic solid waste

| Alternatives | Score values | Ranks |
|---|---|---|
| $O_1$ | −2.01 | 3 |
| $O_2$ | 2.9969 | 1 |
| $O_3$ | −2.00 | 4 |
| $O_4$ | 1.0031 | 2 |

Table 15 shows the net credibility value reflects the worth of capacity and huge engaging quality of the alternatives. According to CRINIRDPR (2016), separated organic waste can be composted using appropriate composting and anaerobic digestion technologies. Owing to the availability of high organic and moisture content, anaerobic digestion is one of the most technically feasible bio-methanation processes for organic solid wastes. Here, the alternative $O_2$-Anaerobic Digestion is the best disposal method for organic waste by proposed method.

### *5.2 Inorganic Waste*

Non-biological waste is a form of waste that does not have a biological basis (industrial origin or any non-natural process). Inorganic wastes are not affected in the slightest by microorganisms that are in the procedure of putrefaction. Therefore, it take a long period to degradable. Meanwhile, organic wastes are biodegradable. They are capable of being decomposed by bacteria or other organisms so they can decompose. Some examples of inorganic waste are aluminum

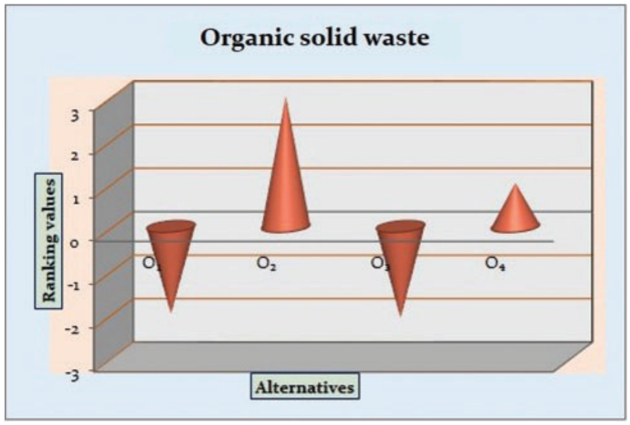



**Figure 5:** Ranking results for organic solid waste

cans, spoons, plastics, and glass. And a few instances of organic waste are paper, cardboard, and food remains. Here, the decision makers evaluate the inorganic waste under the criteria which is represented as an IVq-ROFSs. The linguistic scale can be used to assessment alternatives that can assist experts to clearly express their evidence and viewpoints, which is shown in Tables 3 and 4. We are now analyzing disposal of inorganic waste using the proposed method.

The following alternatives are considered for evaluation: $O_1$-Recycling & Sanitary Landfills, $O_2$-Anaerobic Digestion, $O_3$-Incineration and $O_4$-Aerobic Composting based on the eight criteria by three experts $e_\beta$ and the initial decision matrix for experts with q = 4, as shown in Tables 16–18.

**Table 16:** Decision matrix with linguistic variables for inorganic solid waste-$DM_1$

| | $P_1$ | $P_2$ | $P_3$ | $P_4$ | $P_5$ | $P_6$ | $P_7$ | $P_8$ |
|---|---|---|---|---|---|---|---|---|
| $O_1$ | VG | F | VG | VG | W | G | VG | P |
| $O_2$ | W | P | P | VP | VP | VP | W | W |
| $O_3$ | P | W | W | G | P | VP | G | VP |
| $O_4$ | W | W | F | P | W | P | W | W |

**Table 17:** Decision matrix with linguistic variables for inorganic solid waste-$DM_2$

| | $P_1$ | $P_2$ | $P_3$ | $P_4$ | $P_5$ | $P_6$ | $P_7$ | $P_8$ |
|---|---|---|---|---|---|---|---|---|
| $O_1$ | VG | G | VG | G | VP | VG | VG | W |
| $O_2$ | P | VP | P | VP | VP | P | W | W |
| $O_3$ | W | VP | W | F | W | VP | VG | P |
| $O_4$ | W | P | P | P | W | F | VP | VP |

**Table 18:** Decision matrix with linguistic variables for inorganic solid waste-$DM_3$

| | $P_1$ | $P_2$ | $P_3$ | $P_4$ | $P_5$ | $P_6$ | $P_7$ | $P_8$ |
|---|---|---|---|---|---|---|---|---|
| $O_1$ | G | VG | VG | G | VP | VG | G | W |
| $O_2$ | W | P | VP | P | VP | F | W | W |
| $O_3$ | VG | G | W | VG | G | VG | VG | P |
| $O_4$ | P | VP | VP | P | VP | P | W | VP |

**Step 1:** Determine the significance of each expert. The importance of the weight vector for each expert is $\gamma = (0.45, 0.25, 0.30)$.

**Step 2:** Now, the construct the initial matrix using the linguistic scale, decision makers evaluate the inorganic waste disposal under the selected criterion and the aggregation of the expert's matrix is shown in Table 19.

**Table 19:** The aggregated matrix for inorganic solid waste

| | $P_1$ | $P_2$ | $P_3$ | $P_4$ | $P_5$ | $P_6$ | $P_7$ | $P_8$ |
|---|---|---|---|---|---|---|---|---|
| $O_1$ | ([0.7159, 0.7259], [0.3673, 0.3774]) | ([0.6471, 0.6572], [0.4503, 0.4605]) | ([0.7400, 0.7500], [0.3400, 0.3500]) | ([0.6926, 0.7026], [0.3918, 0.4019]) | ([0.2947, 0.3037], [0.8241, 0.8342]) | ([0.7023, 0.7123], [0.3818, 0.3919]) | ([0.7159, 0.7259], [0.3673, 0.3774]) | ([0.3624, 0.3710], [0.7907, 0.8009]) |
| $O_2$ | ([0.3146, 0.3223], [0.8539, 0.8640]) | ([0.4213, 0.4312], [0.6637, 0.6737]) | ([0.4172, 0.4271], [0.6685, 0.6785]) | ([0.3791, 0.3889], [0.7085, 0.7185]) | ([0.3400, 0.3500], [0.7400, 0.7500]) | ([0.4510, 0.4606], [0.6528, 0.6629]) | ([0.1400, 0.1500], [0.9400, 0.9500]) | ([0.1400, 0.1500], [0.9400, 0.9500]) |
| $O_3$ | ([0.5846, 0.5941], [0.5828, 0.5936]) | ([0.4885, 0.4971], [0.7051, 0.7157]) | ([0.1400, 0.1500], [0.9400, 0.9500]) | ([0.6610, 0.6710], [0.4306, 0.4408]) | ([0.5140, 0.5233], [0.6296, 0.6400]) | ([0.5757, 0.5852], [0.5860, 0.5967]) | ([0.7023, 0.7123], [0.3818, 0.3919]) | ([0.4042, 0.4141], [0.6832, 0.6932]) |
| $O_4$ | ([0.3286, 0.3366], [0.8376, 0.8478]) | ([0.3419, 0.3506], [0.7947, 0.8049]) | ([0.4779, 0.4876], [0.6244, 0.6345]) | ([0.4400, 0.4500], [0.6400, 0.6500]) | ([0.2560, 0.2643], [0.8749, 0.8850]) | ([0.4719, 0.4818], [0.6162, 0.6262]) | ([0.2457, 0.2538], [0.8854, 0.8955]) | ([0.2947, 0.3037], [0.8241, 0.8342]) |

**Step 3:** The significance of each criteria by experts judgment is shown in Table 9. Then, using the IVq-ROFWA aggregation operator we can calculate the criteria's weights using Eq. (11).

**Step 4:** For concordance matrix, the thresholds for alternatives are construct and which is shown in Table 10.

To determine the CCM, it is need to find the $S(O_j)$ and $S(w_j)$, as given in Table 20.

**Table 20:** Results of the alternatives and thresholds for inorganic solid waste

| | $P_1$ | $P_2$ | $P_3$ | $P_4$ | $P_5$ | $P_6$ | $P_7$ | $P_8$ |
|---|---|---|---|---|---|---|---|---|
| $O_1$ | 0.6255 | 0.5690 | 0.6470 | 0.6060 | 0.2676 | 0.6140 | 0.6255 | 0.3085 |
| $O_2$ | 0.2329 | 0.4165 | 0.4130 | 0.3813 | 0.3530 | 0.4279 | 0.1014 | 0.1014 |
| $O_3$ | 0.5005 | 0.4021 | 0.1014 | 0.5804 | 0.4550 | 0.4956 | 0.6140 | 0.4018 |
| $O_4$ | 0.2539 | 0.3025 | 0.4487 | 0.4331 | 0.2025 | 0.4514 | 0.1875 | 0.2676 |
| $T$ | 0.1014 | 0.3530 | 0.4331 | 0.1014 | 0.4967 | 0.1014 | 0.4331 | 0.4331 |
| $F$ | 0.4967 | 0.5669 | 0.3530 | 0.4331 | 0.1014 | 0.4331 | 0.3530 | 0.1014 |
| $M$ | 0.5669 | 0.4967 | 0.5669 | 0.6470 | 0.4331 | 0.4967 | 0.4967 | 0.4967 |

Now, the CCM is determined base on the comparison of the alternatives using Eq. (13), the results shown in Table 21.

**Table 21:** The concordance matrix for inorganic solid waste

| | $O_1$ | $O_2$ | $O_3$ | $O_4$ |
|---|---|---|---|---|
| $O_1$ | 1 | 1 | 0.9169 | 1 |
| $O_2$ | 1.0925 | 1 | 1.1021 | 0.8656 |
| $O_3$ | 0.8317 | 1 | 1 | 1 |
| $O_4$ | 0.9706 | 0.9070 | 0.8694 | 1 |

**Step 5:** The DCM is obtained using (14) and the results are given in Table 22.

**Table 22:** The discordance matrix for inorganic solid waste

| | $P_1$ | | | | $P_2$ | | | | $P_3$ | | | | $P_4$ | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $O_1$ | $O_2$ | $O_3$ | $O_4$ | $O_1$ | $O_2$ | $O_3$ | $O_4$ | $O_1$ | $O_2$ | $O_3$ | $O_4$ | $O_1$ | $O_2$ | $O_3$ | $O_4$ |
| $O_1$ | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| $O_2$ | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 |
| $O_3$ | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0.9004 | 0 | 1 | 0 | 0 | 0 | 1 | 0 |
| $O_4$ | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 |

| | $P_5$ | | | | $P_6$ | | | | $P_7$ | | | | $P_8$ | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $O_1$ | $O_2$ | $O_3$ | $O_4$ | $O_1$ | $O_2$ | $O_3$ | $O_4$ | $O_1$ | $O_2$ | $O_3$ | $O_4$ | $O_1$ | $O_2$ | $O_3$ | $O_4$ |
| $O_1$ | 1 | 0 | 0.2592 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| $O_2$ | 0 | 1 | 0.0018 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | 0.2673 | 1 | 0.5034 | 0.1639 |
| $O_3$ | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 |
| $O_4$ | 0 | 0.1480 | 0.4555 | 1 | 0 | 0 | 0 | 1 | 0.5915 | 0 | 0.5114 | 1 | 0 | 0 | 0.0829 | 1 |

**Step 6:** Then, the comparison between the CCM and DCM are calculated using Eq. (15) and the credibility matrix is given in Table 23.

**Table 23:** The credibility matrix for inorganic solid waste

| | $O_1$ | $O_2$ | $O_3$ | $O_4$ |
|---|---|---|---|---|
| $O_1$ | 1 | 1 | 0.9169 | 1 |
| $O_2$ | 0 | 1 | 1.1021 | 0.8656 |
| $O_3$ | 0 | 1 | 1 | 1 |
| $O_4$ | 0.9706 | 0.9070 | 0 | 1 |

**Step 7:** Finally, according to the Eqs. (16)–(18), the ranking results are obtained and shown in Table 24 and Fig. 6.

Table 24 shows the net credibility value reflects the worth of capacity and huge engaging quality of the alternatives. Recycling saves a substantial amount of industrial, institutional, and bulk inorganic waste from being discarded or disposed of in landfills. This saves scarce money while still reducing environmental impacts. A new landfill that is in compliance with inorganic waste is a sophisticated facility with a variety of facilities designed to reduce environmental impacts. According to CRINIRDPR (2016), inorganic recyclable waste can be sold to government-approved recyclers, and non-recyclable waste can be sent to a local municipality and municipal council for proper landfill. Before planning any waste collection or disposal plants, recycling and sanitary landfill schemes should be implemented. Here, the alternative $O_1$-Recycling & Sanitary Landfills (RC & SL) is the best disposal method for inorganic waste by proposed method.

**Table 24:** The Ranking results for inorganic solid waste

| Alternatives | Score values | Ranks |
|---|---|---|
| $O_1$ | 1.9463 | 1 |
| $O_2$ | −0.9393 | 3 |
| $O_3$ | −0.009 | 4 |
| $O_4$ | −0.988 | 2 |

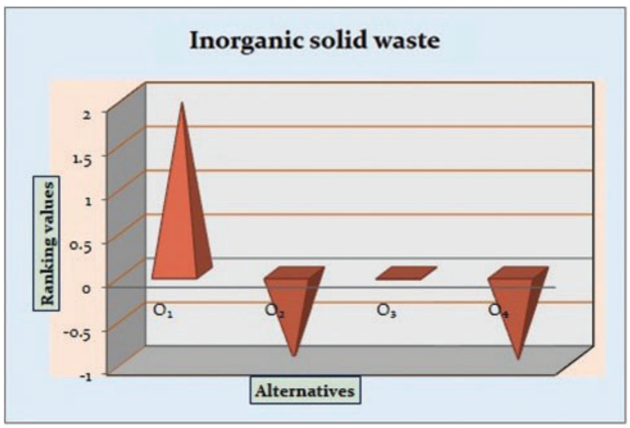


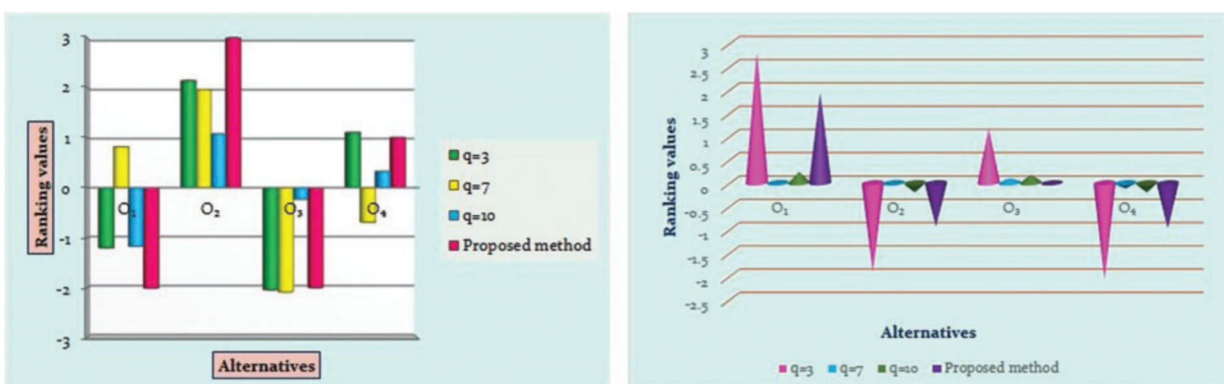

**Figure 6:** Ranking results for inorganic waste

## 6 Result Validation and Discussion

**Sensitivity analysis:** The sensitivity analysis of the proposed solid waste disposal method is shown in this section based on the three cases of parameters q = (3, 7, 10) and the expert weight vector (0.30, 0.45, 0.25). The sensitivity analysis of this model is compared to the results of three cases, which are shown in Table 25 and the graphical representation in Fig. 7. These cases are found here by varying the value of parameter $q$. In this paper, the disposal method is chosen based on eight criteria, which approximate the data ranking in practice. The IV-q-ROFS-ELECTRE III method is used to find alternative ranks. Different scores and ranking results can be obtained by assigning different values to the parameter $q$.

**Table 25:** Sensitivity analysis results

| Category | $q$ values | Xi values | Order | Ranks |
|---|---|---|---|---|
| Organic waste | q = 3 | $S(O_1) = -1.2037$,<br>$S(O_2) = 2.1407$,<br>$S(O_3) = -2.0438$,<br>$S(O_4) = 1.1068$ | $O_2 > O_4 > O_1 > O_3$ | $O_2$ |
| | q = 7 | $S(O_1) = 0.8162$,<br>$S(O_2) = 1.9574$,<br>$S(O_3) = -2.0859$,<br>$S(O_4) = -0.6877$ | $O_2 > O_1 > O_4 > O_3$ | $O_2$ |
| | q = 10 | $S(O_1) = -1.1744$,<br>$S(O_2) = 1.0774$,<br>$S(O_3) = -0.2312$,<br>$S(O_4) = 0.3282$ | $O_2 > O_4 > O_3 > O_1$ | $O_2$ |
| Inorganic waste | q = 3 | $S(O_1) = 2.833$,<br>$S(O_2) = -1.9097$,<br>$S(O_3) = 1.167$,<br>$S(O_4) = -2.0903$, | $O_1 > O_3 > O_4 > O_2$ | $O_1$ |
| | q = 7 | $S(O_1) = 0.0254$,<br>$S(O_2) = -0.0019$,<br>$S(O_3) = 0.0998$,<br>$S(O_4) = -0.1233$ | $O_3 > O_1 > O_2 > O_4$ | $O_3$ |
| | q = 10 | $S(O_1) = 0.2336$,<br>$S(O_2) = -0.204$,<br>$S(O_3) = 0.1762$,<br>$S(D_O) = -0.2058$ | $O_1 > O_3 > O_4 > O_2$ | $O_1$ |




(a) (b)

**Figure 7:** (a) Sensitivity results for organic waste, (b) Sensitivity results for inorganic waste

**Comparative analysis:** The ELECTRE III is compatible with our application when compared to the TOPSIS, MULTIMOORA and MABAC which is depicted in the Figs. 8 and 9. When compared to other methods, the comparison analysis in this paper produces more reasonable and robust results. In summary, as compared to TOPSIS, MULTIMOORA and MABAC methods, ELECTRE III method enforces the inter-comparison of alternatives. Further, the decision results extracted from ELECTRE III method come up with additional information in the form of credibility index of outranking relations among the alternatives which is more useful in the cases when the alternatives in problem are large in number. Moreover, ELECTRE family of methods are more preferable for problems with larger number of alternatives and fewer criteria. The process of exploitation of outranking relations adopted in present extensions of ELECTRE III method is complex and requires more calculations and construction of graphs, whereas our method has simplified it by computing the concordance credibility, discordance credibility, and net credibility degree of each alternative to extract partial pre-ordering of alternatives from outranking relations. The ranking lists for the three methods differ in Table 26 and also shows the ranking order results and the graphical representations are given in Figs. 8 and 9. Here, we only considered eight criteria for evaluating alternatives in this paper, but future studies may use the proposed approach to consider additional criteria such as operating expense, risk factors, and benefits to society.

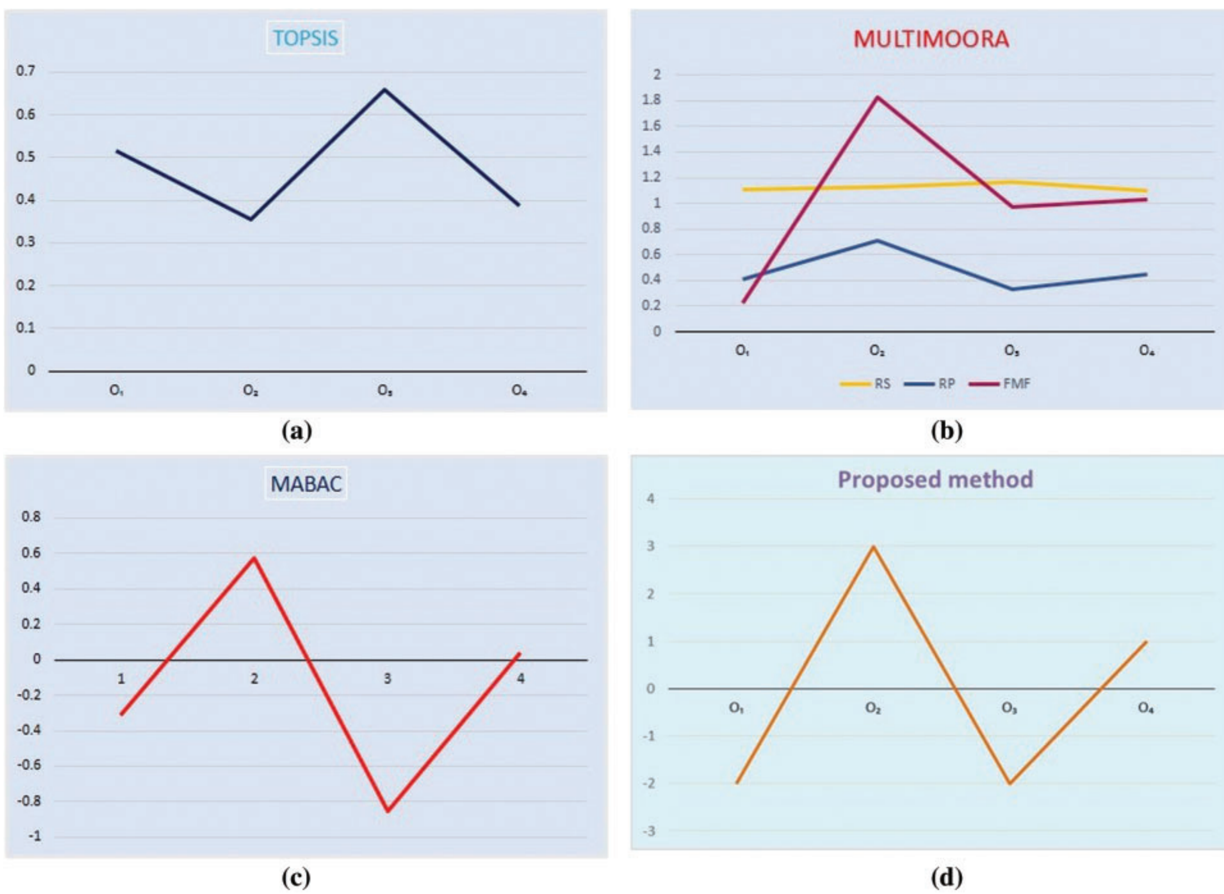



**Figure 8:** Comparison results for organic waste. (a) TOPSIS ranking values (b) MULTIMOORA ranking values (c) MABAC ranking values (d) IVq-ROFS-ELECTRE III ranking values

An ELECTRE III application is divided into two parts: First, the structure of one or more outranking relations with the aim of comparing each pair of acts comprehensively. Second, a protocol for manipulation that expands on the guidelines received in the first phase. The essence of the recommendation is determined by the issue at hand: selecting, rating, or sorting. The ELECTRE III methods are typically used to exclude undesirable solutions to a problem.

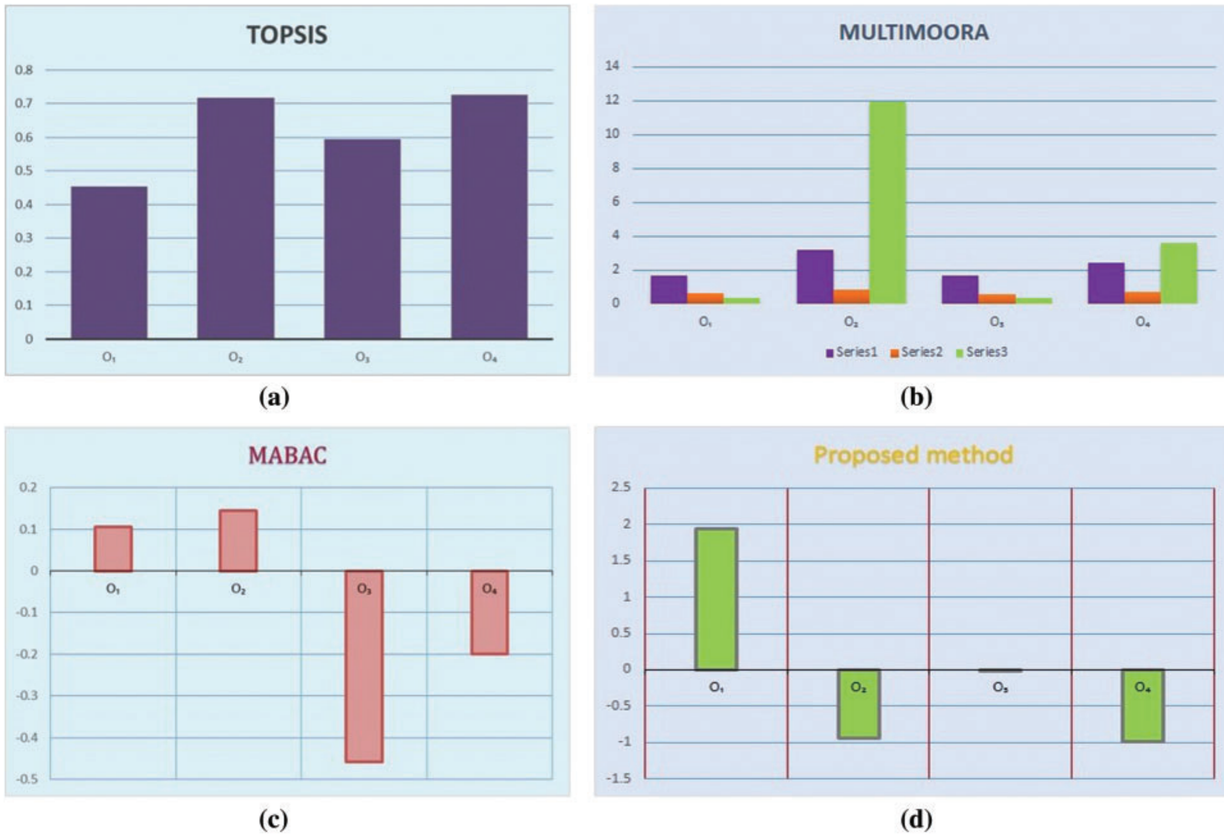



**Figure 9:** Comparison results for inorganic waste. (a) TOPSIS ranking values (b) MULTIMOORA ranking values (c) MABAC ranking values (d) IVq-ROFS-ELECTRE III ranking values

**Table 26:** Comparison results

| Category | Method | Ranking values | Order | Ranks |
|---|---|---|---|---|
| Organic waste | TOPSIS | $O_1 = 0.5149$, $O_2 = 0.3540$, $O_3 = 0.6590$, $O_4 = 0.3866$ | $O_3 > O_1 > O_4 > O_2$ | $O_3$ |

(Continued)

**Table 26:** (continued)

| Category | Method | Ranking values | Order | Ranks |
|---|---|---|---|---|
| | MULTIMOORA (RA,RP,FMF) | $O_1 = (1.1064, 0.4061, 0.2264)$, $O_2 = (1.1243, 0.7135, 1.8246)$, $O_3 = (1.1675, 0.3295, 0.9752)$, $O_4 = (1.0956, 0.4489, 1.0351)$ | $O_3 > O_4 > O_2 > O_1$ | $O_3$ |
| | MABAC | $O_1 = -0.3109$, $O_2 = 0.5719$, $O_3 = -0.8506$, $O_4 = 0.0378$ | $O_2 > O_4 > O_3 > O_1$ | $O_2$ |
| | Proposed method | $O_1 = -2.01$, $O_2 = 2.9969$, $O_3 = -2.00$, $O_4 = 1.0031$ | $O_2 > O_4 > O_1 > O_3$ | $O_2$ |
| Inrganic waste | TOPSIS | $O_1 = 0.4537$, $O_2 = 0.7169$, $O_3 = 0.5956$, $O_4 = 0.7267$ | $O_4 > O_2 > O_3 > O_1$ | $O_4$ |
| | MULTIMOORA (RA,RP,FMF) | $O_1 = (1.674, 0.6145, 0.3785)$, $O_2 = (3.2138, 0.8, 11.9663)$, $O_3 = (1.6949, 0.5395, 0.3682)$, $O_4 = (2.4209, 0.7203, 3.5996)$ | $O_2 > O_4 > O_1 > O_3$ | $O_2$ |
| | MABAC | $O_1 = 0.1048$, $O_2 = 0.1449$, $O_3 = -0.4585$, $O_4 = -0.1993$ | $O_2 > O_1 > O_3 > O_4$ | $O_2$ |
| | Proposed method | $O_1 = 1.9463$, $O_2 = -0.9393$, $O_3 = -0.009$, $O_5 = -0.988$ | $O_1 > O_4 > O_2 > O_3$ | $O_1$ |

As explained previously, the proposed IVq-ROFS-ELECTRE III process has the following advantages:

- The ELECTRE III approach has several advantages in decision-making scenarios. In contrast to ELECTRE II, ELECTRE III is an approach that use a systematic procedure to determine the link between options. The key advantage of this strategy is that the decision maker is directly involved in the decision-making process. ELECTRE III is an interaction approach.

- Another feature of ELECTRE III is the ability to define indifference and preference thresholds. When the data are equivalent and similarly weighted, the options are considered for equally.
- Because of the lesser precision, indifference and preference thresholds are specified to demonstrate their choice or indifference in comparison to other options. This indicates that when the performance of two alternatives is less than the defined quantity in a certain criteria, the alternatives are regarded indifferent in that criterion.
- Finally, the ELECTRE III allows a decision maker to examine both qualitative and quantitative factors at various levels of uncertainty. The establishment of thresholds is a challenge in the implementation of this strategy.
- The advantage of using the ELECTRE III previously is that we can add another MCGDM with a limited set of alternatives, saving us a lot of time. In this processes, criteria have two distinctive sets of structures: significance coefficients and veto thresholds.

## 7 Conclusion and Future Research Directions

### *7.1 Conclusion*

Some of the most notable challenges in waste management include a lack of awareness of health concerns, poor waste control, environmental deterioration, and a lack of financial and human capital. By concentrating on the sorts of garbage that can help us enhance our cleanliness during the COVID-19 epidemic, we have offered organic and inorganic solid waste disposal solutions. In developing nations, trash is often disposed of by burning, landfilling, or dumping, however these procedures are not acceptable for all forms of waste created by SW systems. The new SWM collecting efforts are also planned to include a number of enhancements and innovations due to uncertainty. As a result, when compared to existing decision-making methods, the suggested group decision-aiding two-phase IVq-ROF-ELECTRE III model is more realistically relevant in real-world circumstances. Because an IVq-ROFS may communicate expert preferences in a variety of ways, it has been frequently employed to solve MCDM issues. First, we created a linguistic scale of IVq-ROFNs that included membership and non-membership values in this study. This paradigm allowed for a more comprehensive interpretation of human preference and non-preference data. The suggested method takes use of the ability of IVq-ROF sets to anticipate information on expert-generated uncertainty. The ELECTRE III is chosen as an appropriate approach in this study, and one of its differentiating features is its capacity to handle data with a high degree of uncertainty. Another benefit of the ELECTRE III is that it is completely compatible with environmental cleanup. Furthermore, the ELECTRE III uses pairwise comparison to compare the options. The proportional relevance of each criterion in respect to the decision maker's preference structure is weighted. As a consequence, this version of ELECTRE III outperforms other MCDM approaches. As a result, we recommend that the authorities use our proposed fuzzy ELECTRE III approach to review the choice and examine the alternatives before implementing sustainable policies.

### *7.2 Limitations and Future Research Directions*

The ELECTRE III strategy met the solid waste disposal procedures applicability requirements, according to an observational assessment. Using the ELECTRE III approach (shown in Fig. 2), we built and evaluated our suggested version. These findings reveal that when using the ELECTRE III technique to choose a disposal treatment option, the user cannot acquire erroneous information. Other weight-finding methods, such as subjective or objective weight detection methods, are challenging to combine with the ELECTRE III approach. Because the membership and non-membership values in the investigated solid waste disposal problem are stated as interval numbers, the operators utilised for aggregation in MCGDM approaches struggled to handle them, applying the IVq-ROFS to the suggested solution took longer. We will use the suggested IVq-ROFN-ELECTRE III approach to solve other challenges in the future, such as bio-medical waste disposal and site selection. Furthermore, applying the suggested approach in either a hesitant q-ROFS environment is an intriguing avenue to investigate, since Hq-ROFSs may express fuzzy information more effectively than q-ROFS.

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