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A Novel Assessment of Healthcare Waste Disposal Methods: Intuitionistic Hesitant Fuzzy MULTIMOORA Decision Making Approach

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ABSTRACT Waste produced from medical facilities systems incorporates a blend of dangerous waste which can posture dangers to humans and ecological receptors. Lacking administration of healthcare waste can prompt hazard to medicinal service specialists, patients, public health, communities and the wider environment. Hence, proper management of healthcare waste is imperative to reduce the associated health and environment risk. In this paper, we extend the MULTIMOORA decision making method with intuitionistic hesitant fuzzy set to evaluate the healthcare waste treatment methods. Intuitionistic hesitant fuzzy set is a generalized form of a hesitant fuzzy set. Intuitionistic hesitant fuzzy set considers the uncertainty of data in a single framework and take more information into account. The MULTIMOORA method consists of three parts namely the ratio system, reference point approach and the full multiplicative form. In the optimal ranking methods, the IHF-MULTIMOORA method is uncomplicated it is able to be used practically with high dimension intuitionistic hesitant fuzzy sets. For pathological, pharmaceutical, sharp, solid and chemical wastes, the preferred waste disposal methods are deep burial, incineration, autoclave, deep burial, and chemical disinfection, respectively.

INDEX TERMS Healthcare waste management, intuitionistic fuzzy set, hesitant fuzzy, MULTIMOORA, decision making, MCDM.

I. INTRODUCTION

A good amount of biomedical waste contains infectious elements that are perilous owing to the presence of pathogenic agents. Some of the pathogenic organisms are hazardous, because they may be impervious to harm or have the potency to cause many diseases. Inappropriate waste management will produce disgusting smell and help grow worms, incite environmental hazards, and may even lead to dissemination of diseases like cholera, typhoid, hepatitis etc. The proper hoard and dispersal of medical waste has significant influence since they have direct and indirect impact on health risks to both environment and public health [1]. The World Health Organization (WHO) defines healthcare waste as any waste that is generated from the detection of ailment, treatment, or prevention of the ailment of human beings or animals. It also includes discarded needles and syringes, diagnostic samples, pharmaceuticals, soiled dressings, chemicals, body parts, blood, medical devices and radioactive materials [2]. The generation of healthcare or biomedical waste will be there as long as human civilization is there. It is absolutely necessary that every waste generated from the hospital or healthcare centers should be identified, quantified and segregated. Hospitals ought to effort to scale back waste by dominant inventory, wastage of expendable things and breakages etc. In the healthcare waste management we are able to

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recycle certain things like plastic material, glassware, etc after appropriate cleaning and disinfection.

Waste minimization and recycling, control of toxic air emissions at healthcare waste incinerators, and alternative treatment methods to incineration are the major challenges. There are numerous available and emerging methods to treat regulated healthcare waste. Experts have emphasized minimizing hospital waste as it helps to achieve cost effectiveness and leads to sustainable waste management. Hence developing countries need to focus on sustainable healthcare waste management strategic plans and waste treatment methods. Therefore multi-criteria decision model is proposed for healthcare waste management. The proposed method receives advantages from the abilities of intuitionistic hesitant fuzzy sets to predict uncertainty information given by the experts in the healthcare waste management. We considered main six waste disposal methods. They are: incineration, autoclave, microwave treatment, chemical disinfection, land disposal and deep burial. When the decision makers hesitate between these methods, the healthcare waste management problem comes under MCDM. Intuitionistic hesitant fuzzy sets are utilized to tackle the situations when experts hesitate between the several possible membership and non-membership values to assess alternatives.

Motivated by the above discussion, it is necessary to fill the research gap for healthcare waste disposal methods under fuzzy MULTIMOORA model. In our research, certain differences were detected regarding the criteria used for sorting, collection, storage, transport, treatment and disposal practices. It is found that these differences in waste management criteria could have health implications as well as environmental and economic consequences, both inside and outside the healthcare installations.

The main objective of this research paper is to develop a novel assessment model for healthcare waste disposal. For this we extended the MULTIMOORA decision making model with intuitionistic hesitant fuzzy sets are developed. Then the performance of the developed approach is calculated by numeral approach and application findings are evaluated and studied via comparative analysis.

The rest of the paper is organized as follows: In section 3, we review some basic concepts of IHF sets. In section 4, extended intuitionistic hesitant fuzzy MULTIMOORA method is given. In section 5, a numerical example of healthcare waste management is illustrated to show the efficiency of the proposed method. Then a comparative analysis and discussion are given in section 6 and conclusion and future work are given in section 7.

II. GENERAL REVIEW OF LITERATURE

Several studies have been focused on the management of healthcare waste around the world. See Table 1 for a brief account of some important works from various parts of the world.

Along with these, we would like to highlight some of the methods used in tackling the menace of the healthcare waste. Brent *et al.* [13] utilized the AHP technique to evaluate health care waste management systems in rural areas of developing countries. Fuzzy optimization is used to citing and routing hazardous waste operations in North Carolina with acceptable cost and risks (Warmerdam and Jacobs [14]). Soares *et al.* [15] evaluated the performance of different healthcare waste management scenarios for small generators involving microwaving, autoclave, and lime disinfection, using life cycle assessment (LCA) and life cycle cost(LCC). Tzanakos *et al.* [16] demonstrated that geopolymers were often made with healthcare waste substructure gray as a source. Caniato *et al.* [17] evaluated healthcare waste management methods worldwide within low and middle income countries. He *et al.* [18] presented a technique to reduce the cost and transportation risk in the collection of healthcare waste [18]. Waste treatment methods viz., pyrolysis, steam sterilization, and chemical disinfection were analyzed and afforded information for rectifying the problems which arise in waste management in [19] by Hong *et al*. Mantzaras and Voudrias [20] evolved a conceptual approach to discard the infectious waste and optimized the segregation and treatment processes. Xiao [21] introduced a novel MCDM using D numbers for selecting the best healthcare waste treatment technology. Liu and Wang [22] developed a new multiple attribute decision-making (MADM) method based on q-ROFWABM operator. Yu *et al*. [23] developed a compromise typed variable weight decision method for solving hybrid multi attribute decision making problems with multiple types of attribute values. The compromise-typed variable weight functions are defined and constructed by utility functions.

The Multi-Objective Optimization on the basis of Ratio Analysis (MOORA) approach was proposed by Brauers and Zavadskas [24] and Chen *et al.* [25]. It involves two components, the ratio system approach and the reference point approach. This approach was further developed as MULTIMOORA which was composed of MOORA and of the Full Multiplicative Form of Multiple Objectives. Baležentis *et al.* [26] extended fuzzy MULTIMOORA with linguistic reasoning and group decision making [27]. Li [28] developed some score function and distance measure which are more efficient than the traditional one and extended the MULTIMOORA method with hesitant fuzzy sets [29]. Alcantud and Giarlotta [30] extended the mono-preference approach as a bi-preference approach [31] in decision making with hesitant fuzzy set [32]. Liu *et al.* [33] proposed Fuzzy failure Mode and Effects Analysis (FMEA) risk priority model based on fuzzy MULTIMOORA method to improve prevention of infant abduction. Zhang *et al.* [34] proposes a consensus-based group decision-making framework for FMEA with the aim of classifying FMs into several ordinal risk classes in which we assumed that FMEA participants provide their preferences in a linguistic way using possibility hesitant fuzzy linguistic information. Zavadskas *et al*. [35] proposed the interval-valued intuitionistic fuzzy MULTIMOORA method for solving MCGDM

TABLE 1. A brief survey of the management of healthcare waste around the world.

Author(s)	Study	City/Country
Maamari et al. [3]	Analysis of infectious healthcare waste generation rates and patterns	Lebanon
Bokhoree et al. [4]	Assessment of potential risks associated with medical waste management	Mauritius
Gusca et al. [5]	Comparative analysis of the waste generation rates	Latvia & Kazakhstan
Ikeda [6]	Educational levels of home patients regarding waste management as provided by domiciliary nurses and to identify specific problems	Japan
Manga *et al*. [7]	An evaluation of healthcare waste management systems based on a survey of five health care facilities in the Southwestern region of Cameroon to improve the current practices	Cameroon
Ruoyan *et al*. [8]	Survey of a healthcare waste management system based on a national regulatory framework at the tertiary and secondary hospitals	China
Coker *et al*. [9]	Quantification and characterization of medical waste generated in healthcare facilities	Nigeria
Insaa *et al*. [10]	A study of the regional legislation	Spain
Alagöz *et al*. [2]	The existing situation and management practices such as the amount of the healthcare wastes generated, segregation procedures, collection, temporary storage and transportation of the wastes	Istanbul
Birpinar *et al*. [1]	The current status of the generation, collection, on-site handling, storage, processing, recycling, transportation and safe disposal of medical waste	Istabul, Turkey
Jang *et al*. [11]	An overview of the management practices of medical waste	Korea
Singh *et al*. [12]	The basic issues as definition, categories and principles of handling and disposal of biomedical waste	India

problem and compared it with the already existing methods like IFOWA, INIF- TOPSIS, IVIF-COPRAS, IVIF-WASPAS [36]. Tian *et al.* [37] presented an improved MULTIMOORA approach by integrating the simplified neutrosophic linguistic normalized weighted Bonferroni mean and geometric weighted Bonferroni mean operators and simplified neutrosophic linguistic distance measure. Hafezalkotob and Hafezalkotob [38] evaluated the material selection problem in automotive industry using the fuzzy MULTIMOORA method with Shannon entropy. The MULTIMOORA method with interval fuzzy numbers for solving the material selection problem of power gear was developed by Hafezalkotob *et al*. [39]. Çebi and Otay [40] developed two-stage fuzzy approach in which suppliers selection should be made by using the fuzzy MULTIMOORA method and fuzzy goal programming approach was utilized to allocate the order for selected suppliers [41]. Gou *et al.* [42] introduced the concept of dual hierarchy linguistic term set and utilized it to develop the dual hierarchy hesitant fuzzy linguistic term sets [43]. They also proposed DHFL-MULTIMOORA method for dealing with the MCDM problem. Zhao *et al.* [44] proposed failure mode and effects analysis model in which interval-valued intuitionistic fuzzy continuous weight entropy is applied for risk factor weighting and the IVIF- MULTIMOORA method is used to determine the risk priority order of failure modes [45], [46]. Maghsoodi *et al.* [47] assessed performance appraisal method by applying a multiple criteria decision analysis method such that MULTIMOORA integrated Shannon's entropy significance coefficient [48]. Fattahi and Khalilzadeh [49] proposed a novel hybrid method based on fuzzy FMEA, extended fuzzy MULTIMOORA and fuzzy AHP method for evaluating the various failure modes in steel industry. Hafezalkotob *et al.* [50] presented an overview of MULTIMOORA by analyzing 106 main studies.

III. PRELIMINARIES

Here, we review some basic definitions related to the proposed MULTIMOORA method with intuitionistic hesitant fuzzy information.

Definition 1: An intuitionistic hesitant fuzzy set I on U is represented by using the two functions $h_1(\vartheta)$, $h_2(\vartheta)$. Mathematically, it is represented by following expression:

$$I = \{\langle \vartheta, h_1(\vartheta), h_2(\vartheta)\rangle, \forall \vartheta \in U\},$$

where $h_1(\vartheta) : U \to [0, 1]$ and $h_2(\vartheta) : U \to [0, 1]$ both represent the possible membership degrees and non-membership degrees of the elements $\vartheta \in U$ to the set I. The intuitionistic hesitant fuzzy set satisfies the following conditions:

$$\mu \geq 0, \quad \eta \leq 1, \; 0 \leq \mu^+ + \eta^+ \geq 1, \; \forall \mu \in h_1(\vartheta), \; \eta \in h_2(\vartheta)$$

where μ^+, η^+ are represent the following:

$$\mu^+ \in h_1^+(\vartheta) = \bigcup_{\mu \in h_1(\vartheta)} max\,\{\mu\} \quad \forall\, \vartheta \in U,$$

$$\eta^+ \in h_2^+(\vartheta) = \bigcup_{\eta \in h_2(\vartheta)} max\,\{\eta\} \quad \forall\, \vartheta \in U.$$

Definition 2: Let $\vartheta = \{\mu, \eta\}$, $\vartheta_1 = \{\mu_1, \eta_1\}$ and $\vartheta_2 = \{\mu_2, \eta_2\}$ be any three intuitionistic hesitant fuzzy elements. The basic operation on intuitionistic hesitant fuzzy sets are as follows:

$$\vartheta_1 \oplus \vartheta_2 = \bigcup_{\mu_1,\eta_1 \in \vartheta_1, \mu_2,\eta_2 \in \vartheta_2} \{\{\mu_1 + \mu_2 - \mu_1\mu_2\}, \{\eta_1, \eta_2\}\} \tag{1}$$

$$\vartheta_1 \otimes \vartheta_2 = \bigcup_{\mu_1,\eta_1 \in \vartheta_1, \mu_2,\eta_2 \in \vartheta_2} \{\{\mu_1\mu_2\}, \{\mu_1\mu_2 - \eta_1\eta_2\}\} \tag{2}$$

$$\lambda\vartheta = \bigcup_{\mu,\eta \in \vartheta} \left\{1 - (1-\mu)^\lambda, \eta^\lambda\right\}, \quad \lambda \geq 0 \tag{3}$$

$$\vartheta^\lambda = \bigcup_{\mu,\eta \in \vartheta_1} \left\{\mu^\lambda, 1 - (1-\eta)^\lambda\right\}, \quad \lambda \geq 0. \tag{4}$$

Definition 3: Let $\vartheta_1 = \{\mu_{ij}, \eta_{ij}\}$ and $\vartheta_2 = \{\mu_{ij}, \eta_{ij}\}$ be two IHFSs on $U = \{u_1, u_2, \cdots, u_n\}$. Then the distance measure between ϑ_1 and ϑ_2 is defined as $d(\vartheta_1, \vartheta_2)$, which satisfies the following properties:
(1)$0 \leq d(\vartheta_1, \vartheta_2) \leq 1$;
(2)$d(\vartheta_1, \vartheta_2) = 0$ *if and only if* $d(\vartheta_1 = \vartheta_2)$
(3)$d(\vartheta_1, \vartheta_2) = d(\vartheta_2, \vartheta_1)$
(4) *Let ϑ_3 be any IHFS, if $\vartheta_1 \leq \vartheta_2 \leq \vartheta_3$, then $d(\vartheta_1, \vartheta_2) \leq d(\vartheta_2, \vartheta_3)$ and $d(\vartheta_1, \vartheta_2) \leq d(\vartheta_1, \vartheta_3)$*
The intuitionistic hesitant normalized Hamming distance:

$$d = \frac{1}{2n}\sum_{i=1}^{m}\left[\frac{1}{l}\sum_{j=1}^{n}\left|\mu_{\vartheta_1}^{\sigma(j)} - \mu_{\vartheta_2}^{\sigma(j)}\right| + \frac{1}{n}\sum_{j=1}^{n}\left|\eta_{\vartheta_1}^{\sigma(j)} - \eta_{\vartheta_2}^{\sigma(j)}\right|\right] \tag{5}$$

where $\mu_{\vartheta_1}^{\sigma(j)}$, $\mu_{\vartheta_2}^{\sigma(j)}$ and $\eta_{\vartheta_1}^{\sigma(j)}$, $\eta_{\vartheta_2}^{\sigma(j)}$ are the j^{th} largest values of memberships degree and non-membership degree of ϑ_1 and ϑ_2, respectively.

IV. PROBLEM FORMULATION - PROPOSED METHOD

Assume $A = \{A_1, A_2, \ldots, A_m\}$ be a set of m alternatives and $C = \{C_1, C_2, \ldots, C_n\}$ be a set of n criteria. Here the benefit criteria are ordered as $C_1, C_2, \ldots, C_p$ and the cost criteria as $C_{p+1}, C_{p+2}, \ldots, C_n$. The performance of the alternatives A_i for $(i = 1, 2, \ldots, m)$ with respect to criteria C_j for $(j = 1, 2, \ldots, n)$ is measured by intuitionistic hesitant fuzzy elements,

$$I = \{\vartheta_{ij} \in I\} = \{\{\mu_{ij}^k\}, \{\eta_{ij}^k\}/\mu_{ij}, \eta_{ij} \in \vartheta_{ij}\}$$

If two (or) more decision makers provide the same value, then the values come only once in the ϑ_{ij}, where $k = 1, 2, \ldots, l$ and l is the length of the IVIHFN (or) the number of decision makers / experts.

TABLE 2. Intuitionistic hesitant fuzzy decision matrix.

Alternatives	Criteria			
	C_1	C_2	$\ldots$	C_n
A_1	$\{\mu_{11}^k, \eta_{11}^k\}$	$\{\mu_{12}^k, \eta_{12}^k\}$	$\ldots$	$\{\mu_{1n}^k, \eta_{1n}^k\}$
A_2	$\{\mu_{21}^k, \eta_{21}^k\}$	$\{\mu_{22}^k, \eta_{22}^k\}$	$\ldots$	$\{\mu_{2n}^k, \eta_{2n}^k\}$
$\vdots$	$\vdots$	$\vdots$	$\ddots$	$\vdots$
A_m	$\{\mu_{m1}^k, \eta_{m1}^k\}$	$\{\mu_{m2}^k, \eta_{m2}^k\}$	$\ldots$	$\{\mu_{mn}^k, \eta_{mn}^k\}$

Construct the intuitionistic hesitant fuzzy decision matrix as follows:

$$I = \left[\vartheta_{ij} \in I\right]_{m \times n} = \left\{\left\{\mu_{ij}^k\right\}, \left\{\eta_{ij}^k\right\}/\mu_{ij}, \eta_{ij} \in \vartheta_{ij}\right\}$$

A. MAIN RESULT I

The intuitionistic hesitant fuzzy elements are added up for the benefit criteria and subtracted for the cost criteria. The score values for the benefit criteria and the cost criteria can be calculated by using the equations (1), (2) and are denoted by $S\left(\underset{j \in C_1, C_2, \ldots, C_p}{\oplus} \vartheta_{ij}\right)$ and $S\left(\underset{j \in C_{p+1}, C_{p+2}, \ldots, C_n}{\oplus} \vartheta_{ij}\right)$ where,

$$S\left(\underset{j \in C_1, C_2, \ldots, C_p}{\oplus} \vartheta_{ij}\right) = \sum_{j=1}^{p} w_j\vartheta_{ij} = \frac{1}{l}\sum_{j=1}^{p}\left\{\left\{1 - (1-\mu_{ij})^{w_j}\right\} - \left\{\eta_{ij}^{w_j}\right\}\right\} \tag{6}$$

$$S\left(\underset{j \in C_{p+1}, C_{p+2}, \ldots, C_n}{\oplus} \vartheta_{ij}\right) = \sum_{j=p+1}^{n} w_j\vartheta_{ij} = \frac{1}{l}\sum_{j=p+1}^{n}\left\{\left\{1 - (1-\mu_{ij})^{w_j}\right\} - \left\{\eta_{ij}^{w_j}\right\}\right\} \tag{7}$$

Then we determine the scores of the alternatives using the equation

$$R_i = S\left(\underset{j \in C_1, C_2, \ldots, C_p}{\oplus} \vartheta_{ij}\right) - S\left(\underset{j \in C_{p+1}, C_{p+2}, \ldots, C_n}{\oplus} \vartheta_{ij}\right) \tag{8}$$

$$A_{IHFRP}^* = \{R_i | max_i\, R_i\} \tag{9}$$

The alternatives are ranked by sorting the overall ratio values in the descending order.

B. MAIN RESULT II

In the second part of the IHF- MULTIMOORA method, the optimal objective alternative is determined by the reference point approach.

TABLE 3. Weighted IHF decision matrix.

Alternatives	Criteria			
	C_1	C_2	$\dots$	C_n
A_1	$\{\tilde{\mu}_{11}^k, \tilde{\eta}_{11}^k\}$	$\{\tilde{\mu}_{12}^k, \tilde{\eta}_{12}^k\}$	$\dots$	$\{\tilde{\mu}_{1n}^k, \tilde{\eta}_{1n}^k\}$
A_2	$\{\tilde{\mu}_{21}^k, \tilde{\eta}_{21}^k\}$	$\{\tilde{\mu}_{22}^k, \tilde{\eta}_{22}^k\}$	$\dots$	$\{\tilde{\mu}_{2n}^k, \tilde{\eta}_{2n}^k\}$
$\vdots$	$\vdots$	$\vdots$	$\ddots$	$\vdots$
A_m	$\{\tilde{\mu}_{m1}^k, \tilde{\eta}_{m1}^k\}$	$\{\tilde{\mu}_{m2}^k, \tilde{\eta}_{m2}^k\}$	$\dots$	$\{\tilde{\mu}_{mn}^k, \tilde{\eta}_{mn}^k\}$

To find the ideal alternative based on the reference point approach, the weighted intuitionistic hesitant fuzzy decision matrix R_{ij} was constructed first, where

$$\tilde{I}_{ij} = W_j * I_{ij} \tag{10}$$

The reference point values for benefit criteria ($j \in C_1, C_2, \dots, C_p$) are calculated as follows:

$$r_j = \{max\{\mu_{ij}^k\}, min\{\eta_{ij}^k\}/\mu_{ij}^k, \eta_{ij}^k \in \vartheta_{ij}^k\} \tag{11}$$

Then, the reference point values for the cost criteria ($j \in C_{p+1}, C_{p+2}, \dots, C_n$) are calculated as follows:

$$r_j = \{min\{\mu_{ij}^k\}, max\{\eta_{ij}^k\}/\mu_{ij}^k, \eta_{ij}^k \in \vartheta_{ij}^k\} \tag{12}$$

The maximum deviation $d[(w_j * r_j), (w_j * \tilde{\vartheta}_{ij})]$ from the reference points are calculated by using the normalized Hamming distance measure formula, i.e., equation (13) as.

$$d = \frac{1}{2n}\sum_{i=1}^{n}\left[\frac{1}{l}\sum_{j=1}^{l}\left|\mu_{\vartheta_1}^{\sigma(j)} - \mu_{\vartheta_2}^{\sigma(j)}\right| + \frac{1}{m}\sum_{j=1}^{m}\left|\eta_{\vartheta_1}^{\sigma(j)} - \eta_{\vartheta_2}^{\sigma(j)}\right|\right] \tag{13}$$

The optimal alternative based on this approach is:

$$A_{IHFRP}^* = \{A_i | min_i \, D_i\} \tag{14}$$

where

$$D_i = max \, d[(w_j * \tilde{r}_j), (w_j * \tilde{\vartheta}_{ij})] \tag{15}$$

The alternatives are ranked by sorting the overall reference point values in the ascending order.

C. MAIN RESULT III

For the intuitionistic hesitant fuzzy weighted full multiplicative form, the overall utility of the i^{th} alternative is obtained by using the following equations (16) and (17).

$$S\left(\underset{j \in C_1, C_2, \dots, C_p}{\oplus} \vartheta_{ij}\right) = \sum_{j=1}^{p} \vartheta_{ij}^{w_j}$$

$$= \frac{1}{l}\sum_{j=1}^{p}\left\{\left\{\mu_{ij}^{w_j}\right\} - \left\{1 - (1 - \eta_{ij})^{w_j}\right\}\right\}$$

$$S\left(\underset{j \in C_{p+1}, C_{p+2}, \dots, C_n}{\oplus} \vartheta_{ij}\right) = \sum_{j=p+1}^{n} \vartheta_{ij}^{w_j}$$

$$= \frac{1}{l}\sum_{j=p+1}^{n}\left\{\left\{\mu_{ij}^{w_j}\right\} - \left\{1 - (1 - \eta_{ij})^{w_j}\right\}\right\}$$

$$U_i = S\left(\underset{j \in C_1, C_2, \dots, C_p}{\oplus} \vartheta_{ij}\right) \oslash S\left(\underset{j \in C_{p+1}, C_{p+2}, \dots, C_n}{\oplus} \vartheta_{ij}\right) \tag{16}$$

Here, the intuitionistic hesitant fuzzy elements are multiplied for the benefit criteria, and the intuitionistic hesitant fuzzy elements are divided for the cost criteria.

The optimal alternative by the full multiplicative form is,

$$A_{IHFFMF}^* = \{A_i | max_i \, U_i\} \tag{17}$$

Finally, the alternatives are ranked in descending order. After the calculation of the three ranks, they can be integrated into a final ranking, which is the final IHF-MULTIMOORA rank based on the dominance theory. The dominance theory was proposed as a tool to summarize the three ranks of the alternatives with the IHF-MULTIMOORA method (Brauers and Zavadskas [24]).

V. HEALTHCARE WASTE MANAGEMENT

A. HEALTH RISKS ASSOCIATED WITH HEALTHCARE WASTE

In developing countries, interactions over processes of medical waste on open dump sites are at considerable risks. Waste handlers suffer directly by handling healthcare waste and having occupational hazards or infections and also spread out the infections for their colleagues. Healthcare waste constitutes several significant public health consequences. Healthcare waste has deleterious effects on different groups of people like waste handlers, patients, workers in waste treatment and disposal facilities, healthcare workers and the public directly or indirectly. Diseases related to the improper waste handling are tuberculosis, skin infection, HIV/AIDS, typhoid fever, cholera, diarrhea, hepatitis, bronchitis, diarrhea, skin infection, vomiting, catarrh, food poisoning etc.

B. HEALTHCARE WASTE TREATMENT

In many developing countries, the most common waste disposal methods are dumping in open sites or incinerate with inadequate measures. Such practices are very inefficient and they pose heavy risk to public health and the environment. The handling, transportation and disposal of health care wastes require the development and implementation of sustainable and integrated waste management solutions (Manga *et al.* [7]).

- **Incineration:** Incineration is one of the most preferred waste disposal methods. Although it is cost effective, it is not environmental friendly. Suppose the incinerators are handled or operated improperly then there are a lot of possibilities to emit air with toxic pollutants Jang *et al.* [11].
- **Autoclave:** In the autoclave treatment we deeply penetrate the equipments and materials with the high temperature and steam for destroying the microorganisms. Recently the autoclave machines are designed as automated for reduce the human involvement, the injuries and contamination are also minimized.
- **Microwave:** A microwave disposal treatment is similar such as the autoclave treatment in which microorganisms are decontaminated with the help of heat. Microwave is not suitable for totally solid or dry materials. Moisture in the materials transfix the heat deeply for sterilizing.

TABLE 4. Types of healthcare wastes.

Category	Waste	Collected Waste items
Category I	Pathological waste	Body parts, pus, organs, blood, tissue, cytostatic chemical, genotoxic chemicals,urine bags, dialysis kit, psychotropic substances, etc.
Category II	Pharmaceutical waste	old drugs, tablets, capsules, vaccines, contaminated pharmaceutical products, tubing,vials, half used bottles,unsealed syrups,cream,ointment, liquid medication, etc.
Category III	Sharp waste	Needles, syringes with fixed needles, lab slides, pincers, scissors, lancets, blades, scalpels, broken glass, ampoules, metallic body implants, etc.
Category IV	Solid waste	Dressing materials, bedding, face mask, cap, placenta, beakers, cylinder, tube, bottles, cans, tin, gown, thermometer, blood pressure gauges, cotton pads, bandage, etc.
Category V	Chemical waste	Cleaning compounds, disinfectants, photographic fixing, solvents, fixatives, agents used for chemotherapy, pesticides, acids, rodenticides, mercury, cadium, lead, etc.

- **Chemical disinfection:** Mostly the chemical wastes are directly discarded in the sewage system by the healthcare organizations which may lead to maximum skin infections and diseases to the waste handlers. Chemical disinfection treatment deactivates such chemicals by using certain disinfection. Sodium hypochlorite, calcium hypochlorite, sodium dichloroi socyanurate, chloramine, ethanol, alkaline, glutaraldehyde, formaldehyde/formalin, savlon, chloroxylenol, cresol are some of the most commonly used chemical disinfections.
- **Land disposal:** Land disposal method can be used for the nonhazardous waste or untreated waste that can not be decontaminated by any other methods.
- **Deep burial:** Deep burial waste disposal treatment method is preferred for the infectious waste, which is well suitable for the pathological waste. Deep burial treatment reduces the water contamination and also the pollutants through the air emission.

C. WASTE SEGREGATION

Healthcare waste are generally segregated into the color-coded bags or bins. The commonly used universal bio-hazard signs are placed on all waste containers (Insaa *et al.* [10] and Manga *et al.* [7]). Table 4 illustrates the category of wastes and collected waste items under each category of waste. Proper waste segregation reduces cross contamination and infection due to toxic wastes. Items contaminated with blood and body fluids, tissues, organs etc. form the pathological waste. The pathological waste is a bio-hazard since it is exposed with the hazardous chemicals including chemotherapy drugs. Double care is needed to handle the pathological waste. Double-bagging is often used in such cases. Pharmaceutical waste includes healthcare drugs that are unused, expired, contaminated and the damaged pharmaceutical items. If pharmaceutical waste are stored or disposed incorrectly, they are extremely harmful to the public and environment. Special care and precautions must be needed to diffuse the pharmaceutical waste because of their hazardous nature. Sharps which include both contaminated and used discarded metal sharps like lab slides, pincers, scissors, lancets, blades, scalpels, broken glass, ampoules etc. are segregated in puncture proof, tamper proof and leak proof containers. Chemical waste produced in research facilities, regularly in fluid shape, are not isolated in a large number of the healthcare centers and are discarded through general society sewage systems. Heavy metals, plastic items and bottles are segregated as solid waste and the dressing materials, bedding, cap, face mask etc. are also categorized as the solid waste. Maximum reusable solid wastes like bins, containers, glassware etc. are disinfected using autoclave or microwaving treatments and then sent for recycling.

TABLE 5. Linguistic scale for rating the alternatives.

Linguistic variable	Fuzzy numbers
Very very high	0.1
Very high	0.2
High	0.3
Medium high	0.4
Medium	0.5
Medium low	0.6
Low	0.7
Very low	0.8
Very very low	0.9

D. ADAPTATION OF PROPOSED METHOD IN HWM

To avail the best waste disposal technology for healthcare waste management, various disposal methods are considered here as alternatives and multiple evaluation criteria are considered for evaluating the alternatives. Hence the healthcare waste management problem is turned as the complex multi-criteria decision-making problem. The decision makers/ experts express their individual opinion by using multiple scale linguistic term sets as in Table 5. Due to the involvement of human judgment, various uncertainties are introduced in the healthcare waste disposal process. The technique selected were incineration, autoclave, microwaving, chemical disinfection, landfill, and deep burial. The efficiency of disposal methods was evaluated using a decision-making tool IHF-MULTIMOORA. The criteria chosen to analyze the disposal methods ensure the potential applicability of the techniques and can subsidize the development of public policies that aim to solve the problems of HCW management.

To select the best healthcare waste management method, a committee of three decision makers or experts namely DM1, DM2, DM3 is formed. In this study, ten criteria are considered to evaluate the waste disposal methods by experts as given in Table 6.

TABLE 6. Selected criteria for rating the alternatives.

Criteria	Concept	Description
C_1	Automation	Certain waste disposal treatments are automated to minimize human involvement and reduce injuries and contamination.
C_2	Safety systems	Safety is one most important criterion in waste management. In all waste disposal treatments ensure that correct handling, treatment, storage, and disposal procedures to workers health and safety.
C_3	Cost	There are different types of cost issues associated with every type of treatment technology. Example: capital equipment costs, installation and facility cost, labor salary costs, etc.
C_4	Noise	The unwanted, unpleasant or disagreeable sound that causes discomfort to workers as well as the community.
C_5	Stink	Malodorous gas will be produced in medical waste disposal treatment process, which mainly consists of volatile organic compounds.
C_6	Solid dregs	Solid dregs emission, if any, which are harmful to human health or the environment.
C_7	Water residues	Waste disposal treatments generate water pollution and residues. Dioxin and mercury are examples of such emissions.
C_8	Air pollution	Some waste disposal treatments create air pollution due to gasses and chemicals evaporating from the waste.
C_9	Land requirement	Land requirement for disposal treatment machines and handling waste.
C_{10}	Workers	Number of employees needed to operate the healthcare waste management equipment system.

TABLE 7. Evaluation of the alternatives over the criteria for pathological waste.

Criteria	Alternatives		
	Incineration	Landfill	Deep burial
C_1 Automation	$\{\{0.6,0.6,0.7\},\{0.4,0.3,0.2\}\}$	$\{\{0.9,0.8,0.7\},\{0.1,0.2,0.3\}\}$	$\{\{0.3,0.5,0.4\},\{0.6,0.5,0.6\}\}$
C_2 Safety systems	$\{\{0.3,0.4,0.2\},\{0.6,0.5,0.7\}\}$	$\{\{0.4,0.2,0.5\},\{0.5,0.6,0.3\}\}$	$\{\{0.7,0.8,0.6\},\{0.3,0.1,0.2\}\}$
C_3 Cost	$\{\{0.5,0.4,0.4\},\{0.5,0.4,0.6\}\}$	$\{\{0.4,0.5,0.3\},\{0.6,0.5,0.6\}\}$	$\{\{0.6,0.5,0.3\},\{0.3,0.4,0.5\}\}$
C_4 Noise	$\{\{0.2,0.3,0.2\},\{0.7,0.6,0.7\}\}$	$\{\{0.1,0.2,0.3\},\{0.9,0.8,0.7\}\}$	$\{\{0.2,0.1,0.2\},\{0.7,0.8,0.8\}\}$
C_5 Stink	$\{\{0.8,0.7,0.8\},\{0.1,0.3,0.2\}\}$	$\{\{0.7,0.8,0.8\},\{0.2,0.1,0.2\}\}$	$\{\{0.1,0.2,0.1\},\{0.9,0.8,0.9\}\}$
C_6 Solid dregs	$\{\{0.5,0.7,0.6\},\{0.5,0.2,0.3\}\}$	$\{\{0.8,0.7,0.6\},\{0.2,0.3,0.3\}\}$	$\{\{0.3,0.2,0.1\},\{0.7,0.8,0.8\}\}$
C_7 Water residues	$\{\{0.2,0.3,0.1\},\{0.8,0.7,0.7\}\}$	$\{\{0.5,0.4,0.6\},\{0.5,0.6,0.4\}\}$	$\{\{0.1,0.3,0.2\},\{0.8,0.7,0.8\}\}$
C_8 Air pollution	$\{\{0.9,0.8,0.9\},\{0.1,0.2,0.1\}\}$	$\{\{0.7,0.8,0.6\},\{0.3,0.2,0.3\}\}$	$\{\{0.1,0.2,0.3\},\{0.9,0.8,0.7\}\}$
C_9 Land requirement	$\{\{0.8,0.7,0.7\},\{0.2,0.3,0.3\}\}$	$\{\{0.9,0.7,0.8\},\{0.1,0.3,0.2\}\}$	$\{\{0.5,0.4,0.6\},\{0.5,0.6,0.4\}\}$
C_{10} Workers	$\{\{0.7,0.5,0.6\},\{0.3,0.4,0.3\}\}$	$\{\{0.4,0.6,0.5\},\{0.6,0.4,0.4\}\}$	$\{\{0.5,0.6,0.5\},\{0.4,0.3,0.4\}\}$

TABLE 8. Score values of ratio system approach.

Alternatives	Score values for benefit criteria	Score values for cost criteria
A1	0.6332	0.6338
A5	0.522	0.63
A6	0.5745	0.7718

E. PATHOLOGICAL WASTE

Experts evaluate the pathological waste under the criteria which is represented as an intuitionistic hesitant fuzzy element. The intuitionistic hesitant fuzzy decision matrix is constructed for pathological waste. Table 7 shows the evaluation of the waste category I over the criteria. The following alternatives are considered for evaluation: Incineration-A_1, Landfill-A_5 and Deep burial-A_6. The linguistic scale (Table 5) should be used for evaluating the alternatives which can help decision makers for expressing their hesitant information and opinions clearly.

Now, we evaluate the pathological waste using the proposed method.

- **The intuitionistic hesitant fuzzy ratio System:**

The intuitionistic hesitant fuzzy elements are added up for the benefit criteria and are subtracted for the cost criteria. The score values for the benefit criteria and the cost criteria can be calculated using the equations (6) and (7) as given in Table 8 and Figure 1.

Then we determine the ratio score values of the alternative using the equation (8),

$$R_i = \{4.96, 4.76, 5.62\}$$

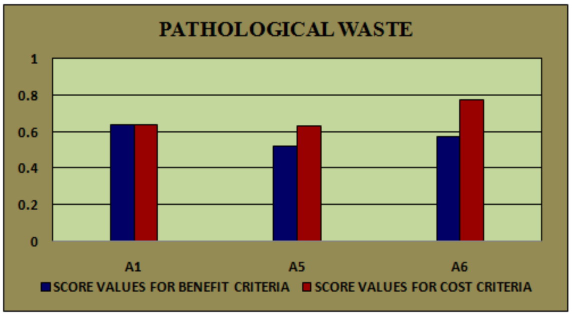

FIGURE 1. Score values of ratio system approach.

TABLE 9. Score values of multiplicative form approach.

Alternative	Score values for benefit criteria	Score values for cost criteria
A1	1.031	1.0199
A5	1.0257	0.9283
A6	1.0062	1.0146

The alternatives are ranked by sorting the overall ratio values in the descending order.

$$A^*_{IHFRS} = \{5.62, 4.96, 4.76, \}$$

- **The intuitionistic hesitant fuzzy reference point approach**

In the second part of the IHF- MULTIMOORA method, the optimal objective alternatives are determined by the reference point approach.

TABLE 10. Ranking the alternatives for pathological waste.

Methods	Pathological waste			
	Incineration- A_1	Landfill- A_5	Deep burial- A_6	Ranking
Ratio system	4.96	4.76	5.62	$\max\{A_6 > A_1 > A_5\}$ - A_6
Reference point approach	0.0705	0.069	0.0746	$\min\{A_5 > A_1 > A_6\}$ - A_6
Multiplicative Form	0.8388	1.1408	0.1702	$\max\{A_5 > A_1 > A_6\}$ - A_5

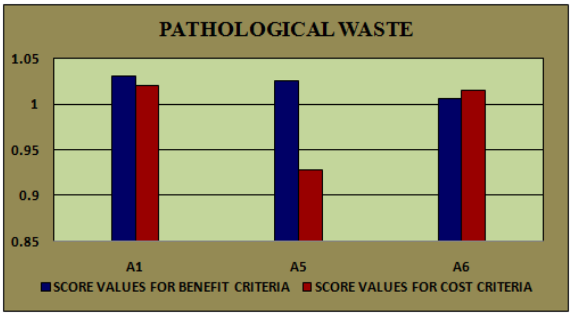

FIGURE 2. Score values of multiplicative form approach.

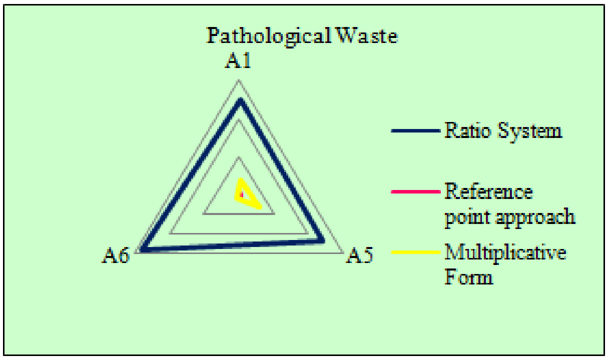

FIGURE 3. Ranking list of pathological waste.

To find the ideal alternative based on the reference point approach, the weighted intuitionistic hesitant fuzzy decision matrix is used.

The maximum deviation $d[(w_j * r_j), (w_j * \tilde{\vartheta}_{ij})]$ from the reference points are calculated using the normalized Hamming distance measure formula, (i.e.,) equations (13) and (15).

The optimal alternative based on this approach is:

$$D_1 = \{0.0705\}, \quad D_2 = \{0.069\}, \; D_3 = \{0.0746\},$$

The alternatives are ranked by sorting the overall reference point values in the ascending order.

$$A^*_{IHFRP} = \{0.069, 0.0705, 0.0746\}$$

- **The intuitionistic hesitant fuzzy weighted full multiplicative form**

In terms of the full multiplicative form the overall utility of the i^{th} alternative is obtained by using the equation (16).

Here the intuitionistic hesitant fuzzy elements are multiplied for benefit criteria, and intuitionistic hesitant fuzzy elements are divided for the cost criteria as shown in Table 9 and Figure 2.

$$U_1 = \{0.8388\}, \quad U_2 = \{1.1408\}, \; U_3 = \{0.1702\}$$

The optimal alternative by the full multiplicative form is,

$$A^*_{IHFFMF} = \{1.1408, 0.8388, 0.1702\}$$

Finally, the alternatives are ranked in the descending order as shown in Table 10 and Figure 3. By using the dominance theory, A_6 - deep burial is the best suitable method for pathological waste.

F. PHARMACEUTICAL WASTE

Experts evaluate the pharmaceutical waste under the criteria which is represented as an intuitionistic hesitant fuzzy element. The intuitionistic hesitant fuzzy decision matrix is constructed for pharmaceutical waste. Table 11 shows the evaluation of the waste category II over the criteria. The following alternatives are considered for evaluation: Incineration-A_1, Landfill-A_5, Deep burial-A_6.

Now, we evaluate the pharmaceutical waste by using the proposed method.

- **The intuitionistic hesitant fuzzy ratio System**

The intuitionistic hesitant fuzzy elements are added up for the benefit criteria and are subtracted for the cost criteria. The score values for the benefit criteria and the cost criteria can be calculated by using the equations (6) and (7) as given in Table 12 and Figure 4.

Then we determine the ratio score values of the alternatives using the equation (8),

$$R_i = \{4.083, 3.012, 3.62\}$$

The alternatives are ranked by sorting the overall ratio values in the descending order.

$$A^*_{IHFRS} = \{4.083, 3.62, 3.012, \}$$

- **The intuitionistic hesitant fuzzy reference point approach**

In the second part of the IHF- MULTIMOORA method, the optimal objective alternative is determined by the reference point approach.

To find the ideal alternative based on the reference point approach, the weighted intuitionistic hesitant fuzzy decision matrix is used.

TABLE 11. Evaluation of the alternatives over the criteria for pharmaceutical waste.

Criteria	Alternatives		
	Incineration	Landfill	Deep burial
C_1 Auomation	$\{\{0.6, 0.7, 0.7\}, \{0.3, 0.3, 0.2\}\}$	$\{\{0.9, 0.8, 0.7\}, \{0.1, 0.2, 0.3\}\}$	$\{\{0.5, 0.5, 0.4\}, \{0.4, 0.5, 0.6\}\}$
C_2 Safety systems	$\{\{0.4, 0.5, 0.3\}, \{0.3, 0.2, 0.1\}\}$	$\{\{0.2, 0.3, 0.1\}, \{0.7, 0.6, 0.5\}\}$	$\{\{0.7, 0.8, 0.6\}, \{0.3, 0.2, 0.2\}\}$
C_3 Cost	$\{\{0.5, 0.3, 0.4\}, \{0.5, 0.6, 0.6\}\}$	$\{\{0.4, 0.5, 0.3\}, \{0.6, 0.5, 0.6\}\}$	$\{\{0.6, 0.5, 0.4\}, \{0.3, 0.4, 0.6\}\}$
C_4 Noise	$\{\{0.2, 0.3, 0.2\}, \{0.7, 0.6, 0.8\}\}$	$\{\{0.2, 0.3, 0.1\}, \{0.9, 0.8, 0.8\}\}$	$\{\{0.1, 0.3, 0.2\}, \{0.8, 0.7, 0.8\}\}$
C_5 Stink	$\{\{0.5, 0.6, 0.4\}, \{0.4, 0.3, 0.5\}\}$	$\{\{0.4, 0.5, 0.3\}, \{0.3, 0.4, 0.2\}\}$	$\{\{0.2, 0.1, 0.2\}, \{0.8, 0.9, 0.7\}\}$
C_6 Solid dregs	$\{\{0.5, 0.6, 0.7\}, \{0.5, 0.3, 0.2\}\}$	$\{\{0.6, 0.7, 0.8\}, \{0.3, 0.2, 0.3\}\}$	$\{\{0.2, 0.3, 0.1\}, \{0.8, 0.7, 0.8\}\}$
C_7 Water residues	$\{\{0.1, 0.3, 0.2\}, \{0.7, 0.7, 0.8\}\}$	$\{\{0.4, 0.6, 0.5\}, \{0.6, 0.4, 0.5\}\}$	$\{\{0.1, 0.3, 0.2\}, \{0.7, 0.7, 0.8\}\}$
C_8 Air pollution	$\{\{0.9, 0.7, 0.7\}, \{0.1, 0.2, 0.3\}\}$	$\{\{0.8, 0.6, 0.7\}, \{0.2, 0.3, 0.1\}\}$	$\{\{0.1, 0.3, 0.4\}, \{0.7, 0.6, 0.6\}\}$
C_9 Land requirement	$\{\{0.7, 0.8, 0.8\}, \{0.3, 0.2, 0.2\}\}$	$\{\{0.5, 0.6, 0.4\}, \{0.5, 0.3, 0.4\}\}$	$\{\{0.6, 0.4, 0.5\}, \{0.4, 0.6, 0.4\}\}$
C_{10} Workers	$\{\{0.4, 0.7, 0.7\}, \{0.3, 0.2, 0.2\}\}$	$\{\{0.5, 0.6, 0.5\}, \{0.4, 0.3, 0.3\}\}$	$\{\{0.5, 0.4, 0.3\}, \{0.5, 0.6, 0.6\}\}$

TABLE 12. Score values of ratio system approach.

Alternatives	Score values for benefit criteria	Score values for cost criteria
A1	0.4843	0.6417
A5	0.6548	0.62
A6	0.6102	0.7504

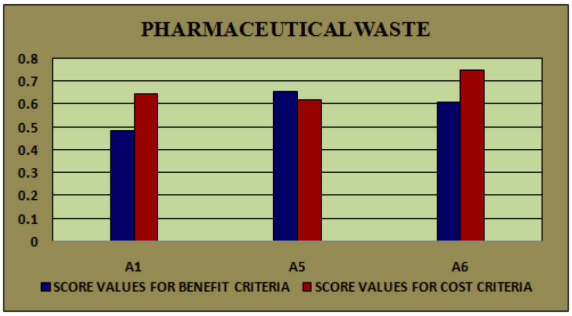

FIGURE 4. Score values of ratio system approach.

TABLE 13. Score values of multiplicative form approach.

Alternative	Score values for benefit criteria	Score values for cost criteria
A1	0.9957	1.0083
A5	1.0355	0.9422
A6	1.03228	1.0065

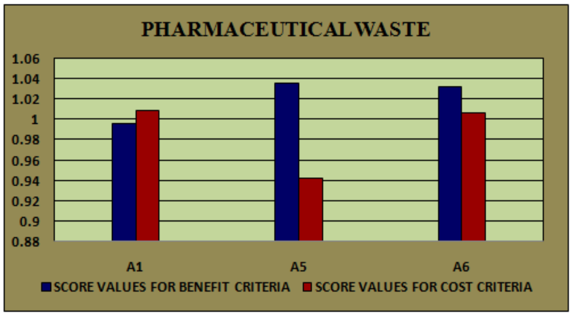

FIGURE 5. Score values of multiplicative form approach.

The maximum deviation $d[(w_j * r_j), (w_j * \tilde{\vartheta}_{ij})]$ from the reference points are calculated by using the normalized Hamming distance measure formula, (i.e.,) equations (13) and (15).

The optimal alternative based on this approach is:

$$D_1 = \{1.8705\}, \ D_2 = \{1.5169\}, \ D_3 = \{1.4976\}$$

The alternatives are ranked by sorting the overall reference point values in the ascending order.

$$A^*_{IHFRP} = \{1.4976, 1.5169, 1.8705\}$$

• **The intuitionistic hesitant fuzzy weighted full multiplicative form**

In terms of the full multiplicative form the overall utility of the i^{th} alternative is obtained by using the equation (16).

Here the intuitionistic hesitant fuzzy elements are multiplied for benefit criteria, and intuitionistic hesitant fuzzy elements are divided for the cost criteria as shown in Table 13 and Figure 5.

$$U_1 = \{2.1993\}, \quad U_2 = \{2.7511\}, \ U_3 = \{2.4368\}$$

The optimal alternative by the full multiplicative form is,

$$A^*_{IHFFMF} = \{2.7511, 2.4368, 2.1993\}$$

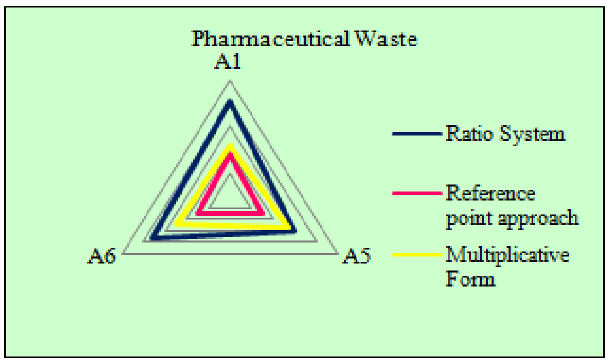

FIGURE 6. Ranking list of pharmaceutical waste.

Finally, the alternatives are ranked in the descending order as shown in Table 14 and Figure 6. By using the dominance theory, A_1 - incineration is the best suitable method for pharmaceutical waste.

G. SHARP WASTE

Experts evaluate the sharp waste under the criteria which is represented as an intuitionistic hesitant fuzzy element. The intuitionistic hesitant fuzzy decision matrix is constructed

TABLE 14. Ranking the alternatives for pharmaceutical waste.

Methods	Pharmaceutical waste			
	Incineration- A_1	Landfill- A_5	Deep burial- A_6	Ranking
Ratio system	4.083	3.012	3.62	$\max\{A_1 > A_6 > A_5\}$ - A_1
Reference point approach	1.8705	1.5169	1.4976	$\min\{A_6 > A_5 > A_1\}$ - A_1
Multiplicative Form	2.1993	2.7511	2.4368	$\max\{A_5 > A_6 > A_1\}$ - A_5

TABLE 15. Evaluation of the alternatives over the criteria for sharp waste.

Criteria	Alternatives			
	Incineration	Autoclave	Microwave	Landfill
C_1 Automation	$\{\{0.4, 0.5, 0.4\}, \{0.3, 0.4, 0.5\}\}$	$\{\{0.6, 0.7, 0.5\}, \{0.4, 0.3, 0.3\}\}$	$\{\{0.5, 0.6, 0.7\}, \{0.4, 0.2, 0.3\}\}$	$\{\{0.5, 0.7, 0.6\}, \{0.4, 0.2, 0.1\}\}$
C_2 Safety system	$\{\{0.3, 0.4, 0.5\}, \{0.7, 0.6, 0.4\}\}$	$\{\{0.9, 0.8, 0.6\}, \{0.1, 0.2, 0.3\}\}$	$\{\{0.7, 0.8, 0.6\}, \{0.2, 0.2, 0.4\}\}$	$\{\{0.3, 0.4, 0.6\}, \{0.6, 0.5, 0.4\}\}$
C_3 Cost	$\{\{0.5, 0.6, 0.5\}, \{0.4, 0.3, 0.4\}\}$	$\{\{0.6, 0.7, 0.5\}, \{0.4, 0.3, 0.3\}\}$	$\{\{0.5, 0.6, 0.7\}, \{0.3, 0.4, 0.3\}\}$	$\{\{0.3, 0.4, 0.5\}, \{0.6, 0.6, 0.5\}\}$
C_4 Noise	$\{\{0.3, 0.4, 0.5\}, \{0.7, 0.6, 0.5\}\}$	$\{\{0.4, 0.5, 0.6\}, \{0.5, 0.4, 0.4\}\}$	$\{\{0.3, 0.2, 0.1\}, \{0.6, 0.7, 0.8\}\}$	$\{\{0.2, 0.1, 0.2\}, \{0.8, 0.7, 02\}\}$
C_5 Stink	$\{\{0.5, 0.4, 0.4\}, \{0.5, 0.6, 0.6\}\}$	$\{\{0.4, 0.3, 0.4\}, \{0.6, 0.5, 0.5\}\}$	$\{\{0.3, 0.4, 0.5\}, \{0.7, 0.6, 0.5\}\}$	$\{\{0.2, 0.1, 0.2\}, \{0.8, 0.7, 0.8\}\}$
C_6 Solid dregs	$\{\{0.8, 0.7, 0.6\}, \{0.2, 0.2, 0.3\}\}$	$\{\{0.1, 0.2, 0.2\}, \{0.7, 0.8, 0.8\}\}$	$\{\{0.2, 0.3, 0.1\}, \{0.7, 0.7, 0.8\}\}$	$\{\{0.7, 0.8, 0.6\}, \{0.3, 0.2, 0.3\}\}$
C_7 Water residues	$\{\{0.1, 0.2, 0.3\}, \{0.7, 0.8, 0.7\}\}$	$\{\{0.7, 0.6, 0.6\}, \{0.3, 0.5, 0.5\}\}$	$\{\{0.6, 0.7, 0.8\}, \{0.4, 0.3, 0.2\}\}$	$\{\{0.6, 0.5, 0.6\}, \{0.4, 0.4, 0.3\}\}$
C_8 Air pollution	$\{\{0.9, 0.8, 0.7\}, \{0.1, 0.2, 0.2\}\}$	$\{\{0.5, 0.4, 0.5\}, \{0.4, 0.3, 0.4\}\}$	$\{\{0.5, 0.5, 0.6\}, \{0.4, 0.5, 0.5\}\}$	$\{\{0.4, 0.3, 0.4\}, \{0.6, 0.7, 0.6\}\}$
C_9 Land requirement	$\{\{0.5, 0.7, 0.8\}, \{0.3, 0.3, 0.2\}\}$	$\{\{0.6, 0.5, 0.6\}, \{0.3, 0.4, 0.3\}\}$	$\{\{0.4, 0.3, 0.2\}, \{0.6, 0.7, 0.8\}\}$	$\{\{0.9, 0.8, 0.7\}, \{0.1, 0.2, 0.3\}\}$
C_{10} Workers	$\{\{0.6, 0.5, 0.5\}, \{0.5, 0.4, 0.5\}\}$	$\{\{0.7, 0.6, 0.7\}, \{0.3, 0.4, 0.3\}\}$	$\{\{0.6, 0.8, 0.7\}, \{0.4, 0.2, 0.3\}\}$	$\{\{0.6, 0.4, 0.6\}, \{0.4, 0.5, 0.4\}\}$

TABLE 16. Score values of ratio system approach.

Alternatives	Score values for benefit criteria	Score values for cost criteria
A1	0.5951	0.6355
A2	0.5743	0.6707
A3	0.5783	0.6448
A4	0.589	0.6764

for sharp waste. Table 15 shows the evaluation of the waste category III over the criteria. The following alternatives are considered for evaluation: Incineration-A_1, Autoclave-A_2, Microwave-A_3 and Landfill-A_5.

Now, we evaluate the sharp waste by using the proposed method.

- **The intuitionistic hesitant fuzzy ratio System**

The intuitionistic hesitant fuzzy elements are added up for the benefit criteria and are subtracted for the cost criteria. The score values for the benefit criteria and the cost criteria can be calculated by using the equations (6) and (7) as given in Table 16 and Figure 7.

Then we determine the ratio score values of the alternatives using the equation (8),

$$R_i = \{4.1246, 5.76, 4.712, 5.0124\}$$

The alternatives are ranked by sorting the overall ratio values in the descending order.

$$A^*_{IHFRS} = \{5.76, 5.0124, 4.712, 4.1246\}$$

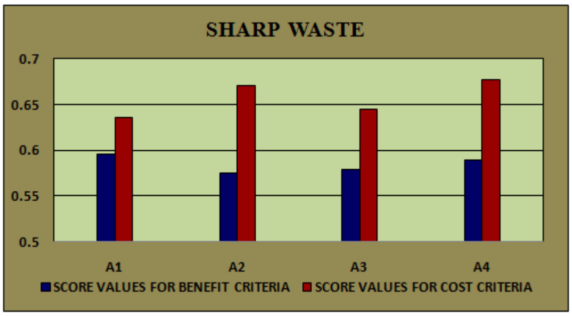

FIGURE 7. Score values of ratio system approach.

TABLE 17. Score values of multiplicative form approach.

Alternative	Score values for benefit criteria	Score values for cost criteria
A1	1.0538	1.0109
A2	1.0044	1.016
A3	1.0509	0.9914
A4	1.0274	0.9908

- **The intuitionistic hesitant fuzzy reference point approach**

In the second part of the IHF- MULTIMOORA method, the optimal objective alternative is determined by the reference point approach.

To find the ideal alternative based on the reference point approach, the weighted intuitionistic hesitant fuzzy decision matrix is used.

TABLE 18. Ranking the alternatives for Sharpe waste.

Methods	Sharpe waste				
	Incineration- A_1	Autoclave- A_2	Microwaving- A_3	Chemical disinfection- A_4	Ranking
Ratio system	4.1246	5.76	4.712	5.0124	$\max\{A_2 > A_4 > A_3 > A_1\}$ - A_2
Reference point approach	1.9705	2.089	2.0746	2.025	$\min\{A_1 > A_4 > A_3 > A_2\}$ - A_2
Multiplicative Form	2.6271	2.1702	2.8438	2.5389	$\max\{A_3 > A_1 > A_4 > A_2\}$ - A_3

TABLE 19. Evaluation of the alternatives over the criteria for solid waste.

Criteria	Alternatives			
	Incineration	Autoclave	Microwave	Deep burial
C_1 Automation	$\{\{0.4, 0.5, 0.6\}, \{0.4, 0.3, 0.4\}\}$	$\{\{0.4, 0.3, 0.4\}, \{0.5, 0.6, 0.5\}\}$	$\{\{0.5, 0.4, 0.6\}, \{0.3, 0.4, 0.3\}\}$	$\{\{0.5, 0.6, 0.6\}, \{0.5, 0.4, 0.4\}\}$
C_2 Safety system	$\{\{0.6, 0.4, 0.5\}, \{0.4, 0.6, 0.4\}\}$	$\{\{0.7, 0.6, 0.8\}, \{0.3, 0.2, 0.2\}\}$	$\{\{0.7, 0.5, 0.8\}, \{0.3, 0.2, 0.1\}\}$	$\{\{0.1, 0.2, 0.3\}, \{0.7, 0.8, 0.7\}\}$
C_3 Cost	$\{\{0.7, 0.6, 0.5\}, \{0.3, 0.4, 0.3\}\}$	$\{\{0.5, 0.6, 0.7\}, \{0.5, 0.3, 0.2\}\}$	$\{\{0.7, 0.6, 0.8\}, \{0.3, 0.4, 0.2\}\}$	$\{\{0.5, 0.4, 0.5\}, \{0.3, 0.2, 0.3\}\}$
C_4 Noise	$\{\{0.6, 0.5, 0.4\}, \{0.3, 0.4, 0.4\}\}$	$\{\{0.6, 0.7, 0.5\}, \{0.3, 0.2, 0.3\}\}$	$\{\{0.3, 0.4, 0.5\}, \{0.6, 0.3, 0.4\}\}$	$\{\{0.1, 0.2, 0.3\}, \{0.7, 0.6, 0.7\}\}$
C_5 Stink	$\{\{0.7, 0.6, 0.8\}, \{0.3, 0.3, 0.2\}\}$	$\{\{0.5, 0.4, 0.3\}, \{0.4, 0.5, 0.4\}\}$	$\{\{0.3, 0.4, 0.4\}, \{0.7, 0.6, 0.6\}\}$	$\{\{0.7, 0.8, 0.7\}, \{0.3, 0.2, 0.3\}\}$
C_6 Solid dregs	$\{\{0.6, 0.8, 0.7\}, \{0.4, 0.2, 0.3\}\}$	$\{\{0.4, 0.2, 0.2\}, \{0.4, 0.6, 0.7\}\}$	$\{\{0.4, 0.5, 0.4\}, \{0.3, 0.5, 0.6\}\}$	$\{\{0.7, 0.8, 0.8\}, \{0.3, 0.2, 0.1\}\}$
C_7 Water residues	$\{\{0.4, 0.3, 0.5\}, \{0.4, 0.6, 0.4\}\}$	$\{\{0.7, 0.6, 0.7\}, \{0.3, 0.4, 0.2\}\}$	$\{\{0.7, 0.6, 0.6\}, \{0.3, 0.4, 0.4\}\}$	$\{\{0.5, 0.4, 0.3\}, \{0.4, 0.3, 0.5\}\}$
C_8 Air pollution	$\{\{0.7, 0.9, 0.8\}, \{0.2, 0.1, 0.2\}\}$	$\{\{0.6, 0.5, 0.4\}, \{0.3, 0.3, 0.4\}\}$	$\{\{0.5, 0.4, 0.5\}, \{0.4, 0.4, 0.3\}\}$	$\{\{0.5, 0.6, 0.6\}, \{0.6, 0.4, 0.3\}\}$
C_9 Land requirement	$\{\{0.7, 0.8, 0.6\}, \{0.2, 0.2, 0.3\}\}$	$\{\{0.5, 0.5, 0.4\}, \{0.4, 0.4, 0.3\}\}$	$\{\{0.4, 0.4, 0.2\}, \{0.6, 0.4, 0.3\}\}$	$\{\{0.7, 0.8, 0.7\}, \{0.3, 0.4, 0.2\}\}$
C_{10} Worker	$\{\{0.6, 0.7, 0.6\}, \{0.4, 0.3, 0.4\}\}$	$\{\{0.5, 0.4, 0.5\}, \{0.4, 0.6, 0.3\}\}$	$\{\{0.6, 0.7, 0.6\}, \{0.4, 0.3, 0.4\}\}$	$\{\{0.5, 0.4, 0.3\}, \{0.5, 0.6, 0.7\}\}$

The maximum deviation $d[(w_j * r_j), (w_j * \tilde{\vartheta}_{ij})]$ from the reference points are calculated using the normalized Hamming distance measure formula, (i.e.,) equations (13) and (15).

The optimal alternative based on this approach is:

$$D_1 = \{1.9705\}, \quad D_2 = \{2.089\},$$
$$D_3 = \{2.0746\}, \quad D_4 = \{2.025\}$$

The alternatives are ranked by sorting the overall reference point values in the ascending order.

$$A^*_{IHFRP} = \{1.9705, 2.025, 2.0746, 2.089\}$$

• The intuitionistic hesitant fuzzy weighted full multiplicative form

In terms of the full multiplicative form the overall utility of the i^{th} alternative is obtained using the equation (16).

Here the intuitionistic hesitant fuzzy elements are multiplied for the benefit criteria, and intuitionistic hesitant fuzzy elements are divided for the cost criteria as shown in Table 17 and Figure 8.

$$U_1 = \{2.6271\}, \quad U_2 = \{2.1702\},$$
$$U_3 = \{2.8438\}, \quad U_4 = \{2.5389\}$$

The optimal alternative by the full multiplicative form is,

$$A^*_{IHFFMF} = \{2.8438, 2.6271, 2.5389, 2.1702\}$$

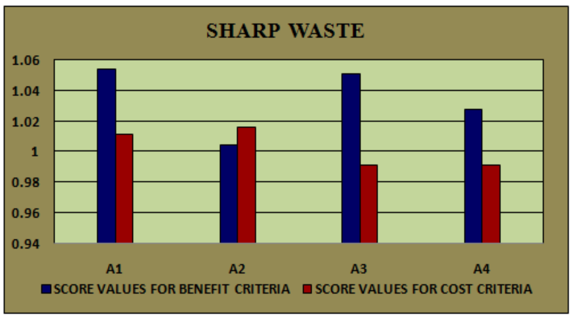

FIGURE 8. Score values of multiplicative form approach.

Finally, the alternatives are ranked in the descending order as shown in Table 18 and Figure 9. By using the dominance theory, A_2 - autoclave is the best suitable method for sharp waste.

H. SOLID WASTE

Experts evaluate the solid waste under the criteria which represented as an intuitionistic hesitant fuzzy element. The intuitionistic hesitant fuzzy decision matrix is constructed for solid waste. Table 19 shows the evaluation of the waste category IV over the criteria. The following alternatives are considered for evaluations: Incineration-A_1, Autoclave-A_2, Microwave-A_3 and Deep burial-A_6.

Now, we evaluate the sharp waste by using the proposed method.

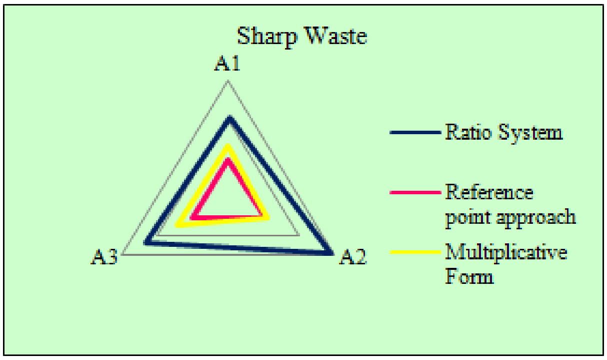

FIGURE 9. Ranking list of sharp waste.

TABLE 20. Score values of ratio system approach.

Alternatives	Score values for benefit criteria	Score values for cost criteria
A1	0.592	0.6014
A2	0.5502	0.5879
A3	0.6279	0.5576
A6	0.746	0.6123

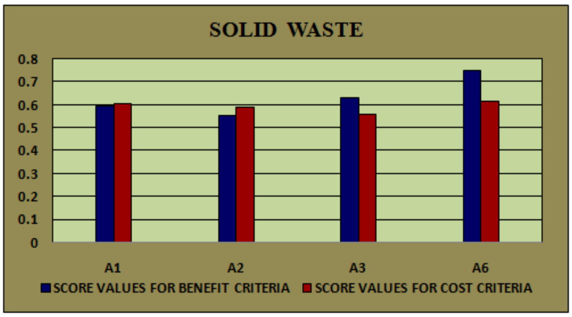

FIGURE 10. Score values of ratio system approach.

• **The intuitionistic hesitant fuzzy ratio System**

The intuitionistic hesitant fuzzy elements are added up for the benefit criteria and are subtracted for the cost criteria. The score values for the benefit criteria and the cost criteria can be calculated using the equations (6) and (7) as given in Table 20 and Figure 10.

Then we determine the ratio score values of the alternative using the equation (8),

$$R_i = \{2.536, 2.126, 2.062, 2.9120\}$$

The alternatives are ranked by sorting the overall ratio values in the descending order.

$$A^*_{IHFRS} = \{2.9120, 2.536, 2.126, 2.062\}$$

• **The intuitionistic hesitant fuzzy reference point approach**

In the second part of the IHF- MULTIMOORA method, the optimal objective alternative is determined by the reference point approach.

TABLE 21. Score values of multiplicative form approach.

Alternative	Score values for benefit criteria	Score values for cost criteria
A1	0.9696	1.0191
A2	1.0231	1.0219
A3	1.0421	1.0191
A6	1.0253	1.0446

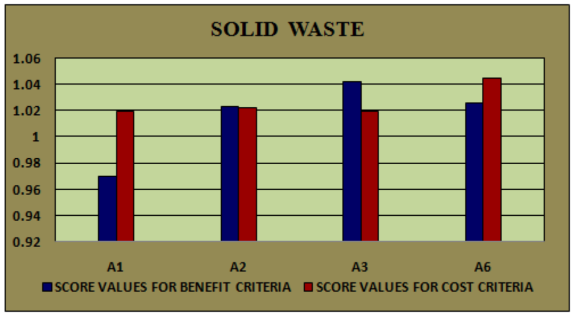

FIGURE 11. Score values of multiplicative form approach.

To find the ideal alternative based on the reference point approach, the weighted intuitionistic hesitant fuzzy decision matrix is used.

The maximum deviation $d[(w_j * r_j), (w_j * \tilde{\vartheta}_{ij})]$ from the reference points are calculated by using the normalized Hamming distance measure formula, (i.e.,) equations (13) and (15).

The optimal alternative based on this approach is:

$$D_1 = \{3.0705\}, \quad D_2 = \{2.069\}, \quad D_3 = \{2.1746\}, \quad D_4 = \{3.4215\}$$

The alternatives are ranked by sorting the overall reference point values in the ascending order.

$$A^*_{IHFRP} = \{2.069, 2.1746, 3.0705, 3.4215\}$$

• **The intuitionistic hesitant fuzzy weighted full multiplicative form**

In terms of the full multiplicative form the overall utility of the i^{th} alternative is obtained using the equation (16).

Here the intuitionistic hesitant fuzzy elements are multiplied for the benefit criteria, and the intuitionistic hesitant fuzzy elements are divided for the cost criteria as shown in Table 21 and Figure 11.

$$U_1 = \{1.1409\}, \quad U_2 = \{2.0563\}, \quad U_3 = \{2.8388\}, \quad U_4 = \{1.1703\}$$

The optimal alternative by the full multiplicative form is,

$$A^*_{IHFFMF} = \{2.8388, 2.0563, 1.1703, 1.1409\}$$

Finally, the alternatives are ranked in the descending order as shown in Table 22 and Figure 12. By using the dominance theory, A_1 - incineration is the best suitable method for pharmaceutical waste.

TABLE 22. Ranking the alternatives for solid waste.

Methods	Solid waste				
	Incineration- A_1	Autoclave- A_2	Microwaving- A_3	Deep burial- A_6	Ranking
Ratio system	2.536	2.126	2.062	2.9120	$\max\{A_6 > A_1 > A_2 > A_3\}$ - A_6
Reference point approach	3.0705	2.069	2.1746	3.4215	$\min\{A_2 > A_3 > A_1 > A_6$ - A_6
Multiplicative Form	1.1409	2.0563	2.8388	1.1703	$\max\{A_3 > A_2 > A_6 > A_1\}$ - A_3

TABLE 23. Evaluation of the alternatives over the criteria for chemical waste.

Criteria	Alternatives		
	Chemical disinfection	Land disposal	Deep burial
C_1 Automation	$\{\{0.7, 0.7, 0.5\}, \{0.3, 0.3, 0.5\}\}$	$\{\{0.5, 0.6, 0.7\}, \{0.4, 0.3, 0.3\}\}$	$\{\{0.5, 0.6, 0.6\}, \{0.4, 0.3, 0.1\}\}$
C_2 Safety system	$\{\{0.7, 0.8, 0.6\}, \{0.3, 0.2, 0.3\}\}$	$\{\{0.6, 0.8, 0.6\}, \{0.3, 0.2, 0.4\}\}$	$\{\{0.4, 0.4, 0.6\}, \{0.5, 0.5, 0.4\}\}$
C_3 Cost	$\{\{0.6, 0.7, 0.6\}, \{0.4, 0.3, 0.3\}\}$	$\{\{0.7, 0.6, 0.7\}, \{0.3, 0.4, 0.3\}\}$	$\{\{0.3, 0.4, 0.3\}, \{0.6, 0.5, 0.5\}\}$
C_4 Noise	$\{\{0.5, 0.5, 0.6\}, \{0.5, 0.4, 0.4\}\}$	$\{\{0.4, 0.2, 0.1\}, \{0.6, 0.7, 0.8\}\}$	$\{\{0.3, 0.1, 0.2\}, \{0.7, 0.7, 02\}\}$
C_5 Stink	$\{\{0.4, 0.3, 0.5\}, \{0.6, 0.4, 0.5\}\}$	$\{\{0.3, 0.5, 0.5\}, \{0.7, 0.4, 0.5\}\}$	$\{\{0.2, 0.3, 0.2\}, \{0.8, 0.7, 0.8\}\}$
C_6 Solid dregs	$\{\{0.2, 0.3, 0.3\}, \{0.8, 0.7, 0.6\}\}$	$\{\{0.2, 0.3, 0.1\}, \{0.7, 0.7, 0.8\}\}$	$\{\{0.7, 0.8, 0.6\}, \{0.3, 0.2, 0.3\}\}$
C_7 Water residues	$\{\{0.7, 0.6, 0.6\}, \{0.3, 0.5, 0.5\}\}$	$\{\{0.6, 0.7, 0.8\}, \{0.4, 0.3, 0.2\}\}$	$\{\{0.6, 0.5, 0.6\}, \{0.4, 0.4, 0.3\}\}$
C_8 Air pollution	$\{\{0.6, 0.4, 0.5\}, \{0.4, 0.3, 0.4\}\}$	$\{\{0.5, 0.4, 0.6\}, \{0.4, 0.5, 0.4\}\}$	$\{\{0.4, 0.5, 0.4\}, \{0.5, 0.5, 0.6\}\}$
C_9 Land requirement	$\{\{0.6, 0.5, 0.4\}, \{0.4, 0.4, 0.3\}\}$	$\{\{0.4, 0.3, 0.4\}, \{0.6, 0.7, 0.5\}\}$	$\{\{0.7, 0.8, 0.9\}, \{0.1, 0.2, 0.1\}\}$
C_{10} Workers	$\{\{0.5, 0.6, 0.7\}, \{0.5, 0.4, 0.3\}\}$	$\{\{0.7, 0.8, 0.6\}, \{0.3, 0.2, 0.4\}\}$	$\{\{0.6, 0.4, 0.5\}, \{0.4, 0.5, 0.4\}\}$

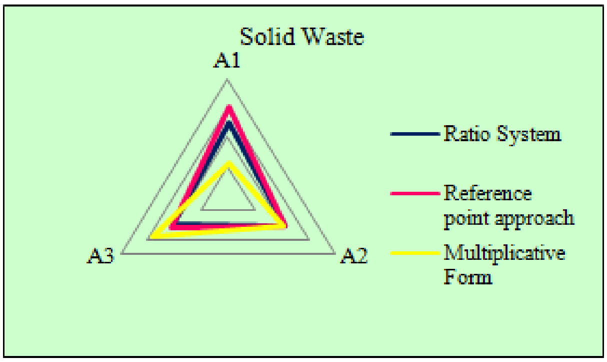

FIGURE 12. Ranking list of solid waste.

I. CHEMICAL WASTE

Experts evaluate the chemical waste under the criteria which is represented as an intuitionistic hesitant fuzzy element. The intuitionistic hesitant fuzzy decision matrix is constructed for chemical waste, Table 23 shows the evaluation of the waste category V over the criteria. The following alternatives are considered for evaluations: Chemical disinfection-A_4, Land disposal-A_5 and Deep burial-A_6.

Now, we evaluate the sharp waste by using the proposed method.

• **The intuitionistic hesitant fuzzy ratio System**

The intuitionistic hesitant fuzzy elements are added up for the benefit criteria and are subtracted for the cost criteria. The score values for the benefit criteria and the cost criteria can be calculated by using the equations (6) and (7) as given in the table 24 and figure 13.

Then we determine the ratio score values of the alternative using the equation (8),

$$R_i = \{5.2361, 4.963, 4.147\}$$

TABLE 24. Score values of ratio system approach.

Alternatives	Score values for benefit criteria	Score values for cost criteria
A4	0.586	0.6473
A5	0.6137	0.6648
A6	0.62	0.6463

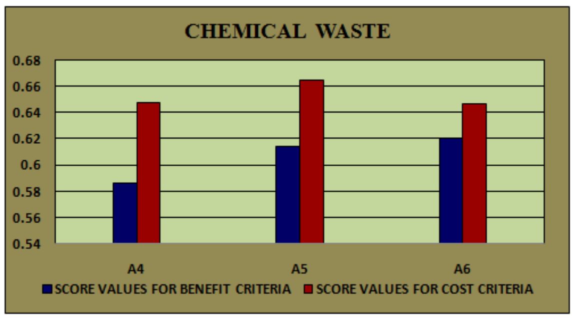

FIGURE 13. Score values of ratio system approach.

TABLE 25. Score values of multiplicative form approach

Alternative	Score values for benefit criteria	Score values for cost criteria
A4	1.029	0.9975
A5	1.0483	0.9999
A6	1.0518	1.0192

The alternatives are ranked by sorting the overall ratio values in the descending order.

$$A^*_{IHFRS} = \{5.2361, 4.963, 4.147\}$$

• **The intuitionistic hesitant fuzzy reference point approach**

In the second part of the IHF- MULTIMOORA method, the optimal objective alternative is determined by the reference point approach.

TABLE 26. Ranking the alternatives for chemical waste.

Methods	Chemical waste			
	Chemical disinfection- A_4	Landfill- A_5	Deep burial- A_6	Ranking
Ratio system	5.2361	4.963	4.147	max$\{A_4 > A_5 > A_6\}$ - A_4
Reference point approach	1.8745	1.256	1.0268	min$\{A_6 > A_5 > A_4\}$ - A_4
Multiplicative Form	0.0698	0.1902	0.1407	max$\{A_5 > A_6 > A_4\}$ - A_5

TABLE 27. Ranking the alternatives by IHF- TOPSIS method.

Waste	Disposal Methods						
	Incineration- A_1	Autoclave- A_2	Microwave- A_3	Chemical disinfection- A_4	Landfill- A_5	Deep burial- A_6	Ranking
Pathological	0.3667	-	-	-	0.4632	2.6151	max$\{A_1 > A_5 > A_6\}$ - A_1
Pharmaceutical	0.2365	-	-	-	0.1887	2.6128	min$\{A_5 > A_1 > A_6\}$ - A_5
Sharp	0.2884	0.2714	-0.3972	-0.0477	-	-	max$\{A_4 > A_3 > A_2 > A_1\}$ - A_4
Solid	0.5667	0.3312	0.2890	-	-	0.3218	max$\{A_3 > A_6 > A_2 > A_1\}$ - A_3
Chemical	-	-	-	0.2678	0.2842	0.0539	min$\{A_6 > A_4 > A_5\}$ - A_6

TABLE 28. Ranking the alternatives by IHF- MULTIMOORA method.

Waste	Methods			
	Ratio system	Reference point approach	multiplicative Form	Ranking
Pathological	max$\{A_6 > A_1 > A_5\}$- A_6	max$\{A_5 > A_1 > A_6\}$- A_6	max$\{A_5 > A_1 > A_6\}$- A_6	A_6
Pharmaceutical	max$\{A_1 > A_6 > A_5\}$- A_1	max$\{A_6 > A_5 > A_1\}$- A_1	max$\{A_5 > A_6 > A_1\}$- A_5	A_1
Sharp	max$\{A_2 > A_4 > A_3 > A_4\}$- A_2	max$\{A_1 > A_4 > A_3 > A_2\}$- A_2	max$\{A_3 > A_1 > A_4 > A_2\}$- A_3	A_2
Solid	max$\{A_6 > A_1 > A_2 > A_3\}$- A_6	max$\{A_2 > A_3 > A_1 > A_6\}$- A_6	max$\{A_3 > A_2 > A_6 > A_1\}$ - A_3	A_6
Chemical	max$\{A_4 > A_5 > A_6\}$- A_4	max$\{A_6 > A_5 > A_4\}$- A_4	max$\{A_5 > A_6 > A_4\}$- A_5	A_4

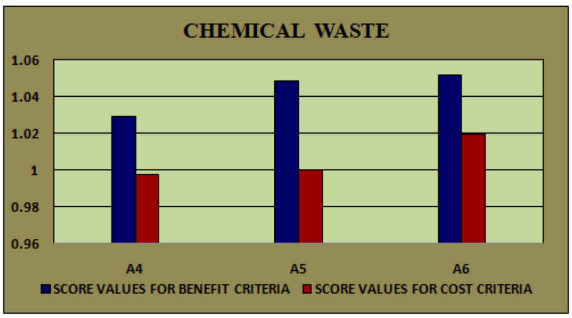

FIGURE 14. Score values of multiplicative form approach.

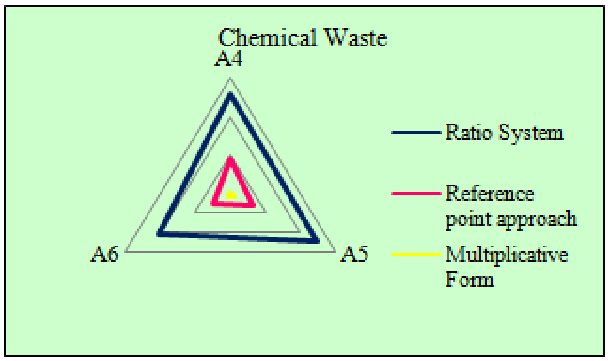

FIGURE 15. Ranking list of chemical waste.

To find the ideal alternative based on the reference point approach, the weighted intuitionistic hesitant fuzzy decision matrix is used.

The maximum deviation $d[(w_j * r_j), (w_j * \tilde{\vartheta}_{ij})]$ from the reference points are calculated by using the normalized Hamming distance measure formula, (i.e.,) equations (13) and (15).

The optimal alternative based on this approach is:

$$D_1 = \{1.8745\}, \quad D_2 = \{1.256\}, \ D_3 = \{1.0268\}$$

The alternatives are ranked by sorting the overall reference point values in the ascending order.

$$A^*_{IHFRP} = \{1.0268, 1.256, 1.8745\}$$

• **The intuitionistic hesitant fuzzy weighted full multiplicative form**

In terms of the full multiplicative form the overall utility of the i^{th} alternative is obtained by using the equation (16).

Here the intuitionistic hesitant fuzzy elements are multiplied for benefit criteria, and intuitionistic hesitant fuzzy elements are divided for the cost criteria as shown in Table 25 and Figure 14.

$$U_1 = \{0.0698\}, \quad U_2 = \{0.1902\}, \ U_3 = \{0.1407\}$$

The optimal alternative by the full multiplicative form is,

$$A^*_{IHFFMF} = \{0.1902, 0.1407, 0.0698\}$$

Finally, the alternatives are ranked in the descending order as shown in Table 26 and figure 15. By using the dominance theory, A_4 - chemical disinfection is the best suitable method for chemical waste.

VI. COMPARISON AND SENSITIVITY ANALYSIS

Finally we compared the proposed method with the intuitionistic hesitant fuzzy TOPSIS method ([51], [52]) as shown in the Table 27. Here Cc_i represents the closest coefficient values in IHF-TOPSIS method. In the TOPSIS method distances are summed but criteria types are not considered.

So the TOPSIS method has less efficiency to rank the alternatives with ideal solution. Therefore, we utilized the proposed IHF-MULTIMOORA method to select the best waste management treatment since it has a high superiority over the other MCDM methods. We summarize the three different approaches. First, the uncertainty of the decision maker in his judgments both membership and non-membership values should be taken into consideration. The proposed approach ranks alternatives according to the three ordering methods, and then, uses dominance theory to combine the three rankings into a single ranking. In the optimal ranking methods, the IHF-MULTIMOORA method is uncomplicated and is good to be used practically with high dimension intuitionistic hesitant fuzzy sets. In order to achieve a healthier environment, it should help to make refinements and gradually move towards a sustainable system. In the disposal methods, certain differences have been made for segregation collection and disposal practices. In waste management, these changes cause a health implication and also the environmental and economic consequences. From the results, as given in the Table 28 for pathological, pharmaceutical, sharp, solid and chemical wastes, preferred waste disposal methods are deep burial, incineration, autoclave, deep burial, and chemical disinfection, respectively. Sensitivity analysis is done with the proposed method. Since the proposed method does not have single part computational section. Its having three different computational parts and the results are gathered using dominance theory.

VII. CONCLUSION AND FUTURE WORK

Generally, the developing countries use incineration or landfilling treatment methods for disposing of the waste but these two methods are not suitable for all waste categories produced by the healthcare systems. The existing healthcare waste management disposal practices still require a lot of changes and developments. Some of the most common problems occurred in waste management are lack of knowledge about the health hazards, insufficient waste management, environmental pollution, inadequate financial and human resources. In this paper, we recommend the waste disposal methods which depends upon the category of waste which may lead us to improve our hygiene, good maintenance and excellent administration of waste management. Promotion of public awareness, enforcement of the legislation and regulations, and the establishment of proper treatment are the principal remedial measures to ensure sound environmental protection.

In this paper, intuitionistic hesitant fuzzy sets are utilized to tackle the situations when experts hesitate between the several possible membership and non-membership values to assess alternatives. The proposed method receives advantages from the abilities of intuitionistic hesitant fuzzy sets to predict uncertainty information given by the experts in the healthcare waste management. The MULTIMOORA method considers three different viewpoints in analyzing decision alternatives. In the future direction, the MULTIMOORA method will be developed based on the D - intuitionistic hesitant fuzzy set that was recently proposed by Li and Chen [53] for reflecting the uncertain environment with the most reliable results.

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(All authors contributed equally to this work.)

CONFLICTS OF INTEREST

The authors declare that there is no conflict of interests regarding the publication of this paper.

AUTHOR CONTRIBUTIONS

All authors have validate and approved the final manuscript.

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