Fuzzy Multi Criteria Group Decision Making with Vikor for Safe Disposal of Commercial Fish Waste

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***Abstract*: The present study primarily concentrates on the waste generated by the fisheries sector and its effect on the human health and environment. Fish wastages attract pathogens, create bad odor, general aesthetic degradation, contamination of water resources and other hazards. Therefore, decision makers move for some alternative methods of disposing commercial fish wastages. Fuzzy mathematical modeling plays an important role in decision making techniques. In this paper we use fuzzy multi criteria group decision making method VIKOR to help the municipal authorities to choose the right alternative method for the safe disposal of commercial fish waste. In this paper, data has been collected from higher officials of Nagapattinam , a coastal area in south India. We suggest four alternative methods for safe disposal of fish waste under three main criteria and nine sub criteria with five linguistic variables from three decision makers.**

***Keywords*: Fish Waste, alternative, criteria, VIKOR, Fuzzy MCDM, Nagapattinam.**

1. Introduction

The word waste means that the substance of concern has no apparent value. The hazard or noxious of the waste determines how a waste should be managed. The waste should undergo a proper treatment to destroy or render them environmentally acceptable. The word today generates about 2.4 billion tons of solid waste every year. Discarded products arise from all human activities. The bio degradable waste includes all plants, animal, human products, the kitchen waste at every home, restaurants, agricultural farms, industries, vegetable markets etc., In coastal area fish waste is the main bio degradable waste which mainly contains organic matters. Traditional composting methods are essentially a biological recycling technology which is being revised and improved with new knowledge of environmental biotechnology. The process of biodegradation in nature can be enhanced by introducing decomposer organisms like earth worms or even bacteria to ferment fish waste. The number of fisheries generated is expected to increase with increase in fish waste, mostly from fish dressing, industrial processing and value addition at every stage.

The disposal of these huge quantities of fish waste can create larger negative impact on environment. Therefore, alternative methods, ecologically acceptable methods of disposal or reutilization of fish waste has to suggested and followed. The aspects of the problems are usually represented in the form of multiple criteria which often creates confusion among the decision makers. In order to raise awareness between the objectives and compare the difference among the alternatives in an optimizing framework, fish waste management decision making may depend on multiple criteria decision making (MCDM) models which promotes participation of all decision makers and synthesis of a wide variety of information. The components involve both quantitative and qualitative factors. These difficulties constitute a method such as fuzzy logic which will be used in uncertainty situation and valuation mathematically in decision making of choosing the apt alternative method.

A. Commercial Fish Waste Management:

Large scale fish processing units face problems on fish waste utilization and safe disposal. Between 5% - 65% of the raw fish goes to waste depending on the processing methods and finished products. Fish waste disposal usually takes the two forms, either dumping of raw fish to sea or in land in a controlled/uncontrolled manner or processing of the waste to by-products using a variety of chemical methods. Disposal of fish waste on agricultural or vacant land has been a long-standing practice but this method became less attractive with the advent of chemical fertilizers and the reduction in the area of agricultural land. The practice of discarding these wastes in dumpsite became more prevalent as waste volume increased. This leads to local environmental problems such as odor, fouling of adjacent water resources, attraction of vermin and general aesthetic degradation. Ground water contamination problems and significant fouling of water courses are also future threats.

2. Review of literature

MADM problem can be associated with a problem of choice or ranking of the existing alternatives (Zimmermann, 1987) [1]. Bellman and Zadeh (1970) introduced the approach regarding decision making in a fuzzy environment [2]. Baas and Kwakernaak (1977) applied the most classic work on the fuzzy MADM method and it was used as a benchmark for other similar fuzzy decision models [3]. Fan et al. (2002) proposed a new approach to solve the MADM problem [4], where the decision makers were instructed to give his/her preference on alternatives in a fuzzy relation. A systematic and consistent decision-making approach to dredging and disposal including contaminated sediment management have been developed in [5]. A multi-objective integer programming approach to select hazardous waste treatment and disposal facilities, and transportation routes have been employed in [6] Radioactive waste attracts a special consideration in hazardous waste literature. In this research stream, [7] proposed a decision support system for the identification of optimal remedial strategies to restore water systems after accidental introduction of radioactive substances. [8] used this decision support system in their study searching for optimum remedial strategies for contaminated lakes. One can deduct from [9] the use of multicriteria decision analysis with an outranking methodology. A review of existing decision-making approaches at hazardous waste management regulatory agencies in the United States and Europe is presented in [10]. The hazards of contaminated dredged material disposal and the associated risks and costs which are highly uncertain have been incorporated in the decision analysis using fuzzy set theory in [11]. A crisp and a fuzzy approach which are applied in dam safety and nuclear industries for risk-based decision analysis are investigated in [12]. One can infer from [13] the use of the approaches investigated in their former paper for the management of contaminated ground water resources problem. VIKOR initiated by [14], of which the compromise solution should have a maximum group utility (majority rule) and minimum individual regret of the opponent, is proposed to deal with multicriteria decision-making problems. A fuzzy approach has been applied to classical VIKOR to capture the imprecision in the evaluations of the decision makers. The use of fuzzy VIKOR is summarized [15], [16]. Various defuzzification strategies have been suggested in the literature. Here we have chosen to use the graded mean integration approach [17]. have proposed a fuzzy VIKOR multicriteria decision analysis for the selection of the most appropriate hazardous waste treatment methodology [18]. Then, an application was presented to show the potential of the proposed methodology for the case of Istanbul. Chitrasen Samantra,andProf. Saurav Datta used fuzzy VIKOR in selecting the supplier [19]. Decision-Making In Fuzzy Environment VIKOR stands for 'VlseKriterijumska Optimizacija I Kompromisno Resenje', means multi-criteria optimization and compromise solution was developed by Opricovic in late 1998 (Opricovic and Tzeng, 2004). [20] VIKOR method is popularly known as multi-criteria decision-making method based on ideal point technique (Opricovic and Tzeng, 2007) [21]. the positive-ideal solutions (best) value and negative-ideal solutions(worst) value for all criterion ratings (Wu and Liu, 2011; Kannan et al., 2009)[22] .Select the best alternative in VIKOR by choosing Q(A(m)) as a best compromise solution with minimum value of Q and must have to satisfy with the conditions (Park et al., 2011)[23].

Transshipment problem has been formulated to a Transportation problem algorithm and TORA Software has been used to analyze the data [37]. Transshipment problem has been formulated to a Transportation problem algorithm and TORA Software has been used to analyze the data [41]. other softwares like Lingo to solve transportation is studied in [53]. Regression models to solve problems in real time is done by [42]. In order to raise awareness between the objectives and compare the difference among the alternatives in an optimizing framework, fish waste management decision making may depend on multiple criteria decision making (MCDM) models which promotes participation of all decision makers and synthesis of a wide variety of information [37]. By the method of linear transformations, the ternary cubic equation with four unknowns is solved for its integral solutions. The equation is researched for its attributes and correlation among the solutions for its non – zero unique integer points [46] and[52]. Interval transportation method to solve minimize cost is referred in [48]. Review study of the authors [49] on transportation scheduling is refered . In Nagapattinam the accumulation of solid waste generation is increases every day because of urbanization. In this paper, three types of waste: Household waste, Industrial waste, Agriculture waste has been studied and it is presented in the form of percentage analysis [44]. Solid waste management by mathematical models will be definitely useful for decision makers for reducing waste, for minimizing travelling cost and also to maximize the usage of dumping yard [37]. The MSW-TSP model is a network in a linear form which owes to minimize the transportation cost. In this paper we have discussed a simple method for solving MSW by transshipment model for arriving optimal solution [39]. Statistical models to analyze challenges faced by tourists [50] and other common problems are studied in [35], [38] and [45]. Perspectives of public is analysed in [34] and 51]. Effectiveness of a data collection is referred in [36].

3. Objective and Methodology

The objective is to help decision makers to choose the appropriate method for safe disposal of fish wastages using MCDM and fuzzy VIKOR method using linguistic data from the decision makers.

The alternative methods proposed to dispose/reutilize the commercial fish waste are as following:

A. Ocean Disposal

Fish waste can be carried to the sea and disposed. The quantity of waste should not create any water quality problems in open water. Benefits are high when a marina free of fish waste is more pleasant. Fish parts disposed will be food for sea birds and other animals. Transportation cost is more in this method.

B. Landfill Disposal

Fish waste can be collected in covered containers and the collected waste is disposed with other solid waste or it can be disposed in local sewage disposal system if nutrient enrichment is not a problem. This keeps fish waste out of water and it does not contaminate sea water. Transportation cost, land cost, environmental health risks are involved.

C. Land Application

Fish waste can be mixed with some chemical/organic matters and turned to compost which can be used as fertilizer for land application. If the processing is properly done the problem of odor, rodents and insects will be minimal. This method will reutilize fish waste and also it has economic benefits when the products are sold(24). Maintenance cost and labor cost are involved in this method. It is a natural way to convert waste to useful soil additive.

D. Processing for Reutilization

If processed the fish waste can be used in plenty of ways. Frozen fish parts can be used as bait for the next fishing trip. The fish waste can be converted to surumi which is a protein recovery from fish waste which when reformed with additives to produce fish sausages. Fish silage, a high-quality fish oil can be produced using fish waste. Fish silage bi-products is used for commercial basis as dog feed and other animal feed (25). It can be used in prawn farms and poultry feed instead of composting. The dry fish waste can be sold to prawn farms and poultry feed producers (26). Labor cost, maintenance cost is involved in this method. Economic benefits and utilization is high in this method.

4. Justification

Safe disposal of fish waste is an important task in managing the municipal solid waste. Managing this huge waste is a daunting task and disposing them at the dumping yards will have an adverse effect on the environment. Selection of best method enhances the environment and human health. Decision makers need mathematical modeling for making their decisions to optimize the offsetting of the waste and increase the benefits. Therefore, the proposed model for group decision makers has been used to evaluate and select the most suitable method for this area for safe disposal of commercial fish waste.

5. Fuzzy Multi Criteria Group Decision Making VIKOR model

Definition 1: Vagueness may exist due to the aspiration levels of goals (Z (x)) and the preference information during the interactive process. For the above case only fuzzy multi-criteria model has come into existence and this can be written as follows:

Min z≈$[z_1(x), z_2(x) \ldots z_k(x)]^T$

S ={ xÎ X/ $\tilde{A}x$ £ $\tilde{b}$, xÎ R^n,x ³0}[27]

Definition 2:A group multiple-criteria decision-making (GMCDM) problem, which may be

described by means of the following, sets (Chen et al., 2006).(28)

i. a set of K decision-makers called $E = \{D1, D2, \ldots Dk\}$
ii. a set of m possible alternatives called $A = \{A1, A2, \ldots Am\}$
iii. a set of n criteria, $C = \{C1, C2, \ldots Cn\}$
iv. a set of performance ratings of $Ai (i = 1,2 \ldots, m)$ with respect to criteria $Cj (j = 1,2, \ldots, n)$ called $X = \{xij. i = 1,2, \ldots, m, j = 1,2, \ldots, n\}$

Definition 3:. A fuzzy set $\widetilde{A}$ in a universe of discourse X is characterized by a membership function $\mu_{\widetilde{A}}(x)$ which associates with each element x in X a real number in the interval [0,1].The function value $\mu_{\widetilde{A}}(x)$ is termed the grade of membership of x in $\widetilde{A}$ (Kaufmann andGupta, 1991)[29].

Definition 4: Suppose, a positive triangular fuzzy number $\widetilde{A}$ and that can be defined as (a,b,c) . The membership function $\mu_{\widetilde{A}}(x)$ is defined as[30](Zadeh 1975).

$$\mu_{\widetilde{A}}(x) = \{\frac{x-a}{b-a}, \text{if } a \le x \le b, \ \frac{c-x}{c-b}, \text{if } b \le x \le c, 0 \text{ otherwise}\}$$

Definition 5: According to the graded mean integration approach, for triangular fuzzy numbers, a fuzzy number $\widetilde{C} = (c1, c2, c3)$ can be transformed into a crisp number [31]by employing the below equation.

$$C = \frac{C1 + 4C2 + C3}{6}$$

Definition 6: A linguistic variable is the variable whose values are not expressed in numbers but words or sentences in a natural or artificial language, i.e., in terms of linguistic (Zadeh,1975)[32]. The concept of a linguistic variable is very useful in dealing with situations, which are too complex or not well defined to be reasonably described in onventional quantitative expressions (Zimmermann, 1991)[33]. For example, 'weight' is a linguistic variable whose values are 'very low', 'low', 'medium', 'high', 'very high', etc. Fuzzy numbers can also represent these linguistic values.

Definition 7: The Serbian name VIKOR stands for '*VlseKriterijumska Optimizacija I Kompromisno Resenje*', means multi-criteria optimization and compromise solution was developed by Opricovic in late 1998 (Opricovic and Tzeng, 2004)[20]. This method concentrates on ranking and selecting the best solution from a set of alternatives, which are associated with multi criteria.The basic principle of VIKOR is to determine the positive-ideal solution as well as negative-ideal (anti-ideal) solution in the search place (Wu and Liu, 2011). The traditional VIKOR method has the following steps(Opricovic and Tzeng 2004,Chang 2010) [21]

Step 1: Compute the positive ideal solutions f_j^* and negative ideal solution f_j^- for all criterion ratings

$$f_j^* = Max\ f_{ij}, j\epsilon C1\ and\ Min\ f_{ij}, J\epsilon C2\ \ , i = 1,2 \dots m$$

$$f_j^- = Min\ f_{ij}, j\epsilon C1\ and\ Max\ f_{ij}, J\epsilon C2\ \ , i = 1,2,\dots,m$$

Here $j = 1,2,\dots,n$ and C_1 is a benefit type criteria set and C_2 is a cost type criteria set.

Step 2: Compute the values of Si and Ri (i=1,2…,m) by using the relation

$$S_i = \sum_{j=1}^{n} W_j\ (f_j^* - f_{ij})/(f_j^* - f_j^-)$$

$$R_i = \max[w_j\ (f_j^* - f_{ij})/(f_j^* - f_j^-)], j = 1,2,\dots,n$$

S_i is the aggregated value of i^{th} alternatives with a maximum group utility and R_i is the aggregated value of of i^{th} alternatives with a minimum individual regret of opponent. W_j is the fuzzy weighted average of each criterion.

Step 3: Compute the values of Q_i for i=1,2..,m using S_i and R_i

$$Q_i = \frac{v(S_i - S^*)}{S^- - S^*} + \frac{(1-v)(R_i - R^*)}{(R^- - R^*)}$$

Here $S^* = \min S_i\ , i = 1,2\dots,m$ $\quad S^- = \max S_i\ , i = 1,2 \dots, m$

and $R^* = \min R_i\ , i = 1,2 \dots, m$ $\quad R^* = \max R_i\ , i = 1,2\dots,m$

v is the weight for strategy of maximum group utility and usually v=0.5.

Step 4: Rank the alternatives by sorting in ascending order.

Step 5:The scheme with minimum Q value is considered to be the best solution for the problem. The alternative should have an acceptable advantage and it also should be best ranked by S and R, then the solution is said to be optimal compromise solution.(Park et al 2011)[23]

Definition 8: Agorithm for fuzzy VIKOR model.

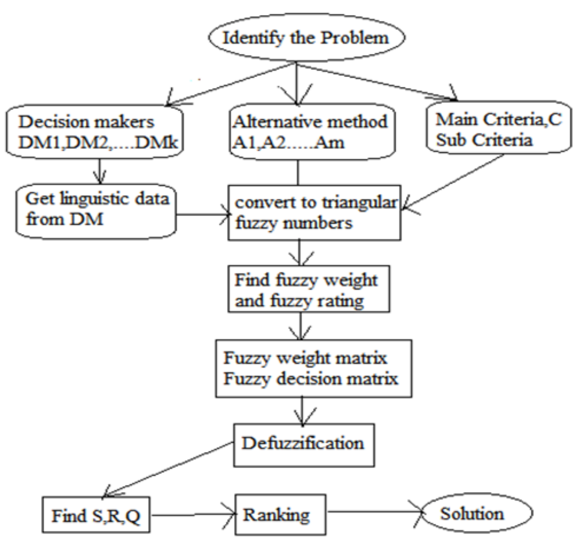

Fig. 1. VIKOR Model

6. Case Study in Nagapattinam Area

Nagapattinam district is an eastern coastal region of Tamil Nadu, India. Major population depends on fishing and its by-products. Everyday tones and tones of sea food are collected from the sea, not only for local consumption but also for export. In every value addition stage of improving the quality of sea foods, leads to lots of wastage. In the boat house and fish markets tons of fish waste due to improper size or poor quality are collected. 44% of the waste is collected from residential areas. 19% from hospitals,17% from fish market, 11% from commercial areas and 9% waste from institutional areas. At present, waste is disposed off through dumping in a disposal yard outside the town. The disposal yard is situated at a distance of 5 km from the town and it is spread over 19 acres. The disposal yard is sufficient for another 15 years. The disposal is done only through dumping. Nagapattinam municipality is in the process of implementing measures to develop the dumping yard and implement composting.

The present work focuses on the fish waste generated in the Nagapattinam town, South India and its practical disposal or reutilization. Apart from sea food, supply of fresh water fishes is from various wetlands within the area and nearby. The fish market in the Nagapattinam Port is the major fish marker in Nagapattinam from where the fishes are exported to other foreign countries and states. The local fish market also receives fish from this port. Around 10 tons of marine fishes are sold in the city every day. The local fish market comprises 150 stalls which supplies the fish requirement of most of the regions of the city. The average fish waste generated during fish dressing in each stall is approximately 600 Kg per day and more than 600 Kg on Sundays (personal communication from stall owners). Thus, the market generates 18 tons/month and 200 tons/year approximately. Therefore, managing this huge waste is a daunting task and disposing them at the dumping yards will have an adverse effect on the environment. Hence the decision makers in the municipality office need to go for disposing methods for safe disposal of fish waste.

There are four alternative methods

A1: Ocean Disposal

A2: Landfill Disposal

A3: Land application

A4: Processing for reutilization

Three main criteria were identified and they are as follows:

MC1: Minimize Economic cost

MC2: Minimize Risk factors

MC3: Maximize technical aspects

And sub criteria under MC1 are C1 to C3, sub criteria under MC2 are C4 to C6 and for MC3 sub criteria are C7 to C9

C1: Capital Cost

C2: Maintenance Cost

C3: Labor Cost

C4: Human health risk

C5: Transportation risk

C6: Ecological risk

C7: Offsetting Waste

C8: Economic Benefits

C9: Endurance

Decision makers have used five linguistic variables for rating alternative methods and also for rating criterions.

Table 1 below shows the weights of linguistic variables and the figure 1 shows the membership values.

Table 1 Weights of linguistic variables

Linguistic variables for weights

Very Low	(0,0,0.25)
Low	(0,0.25,0.5)
Medium	(0.25,0.5,0.75)
High	(0.5,0.75,1)
Very High	(0.75,1,1)

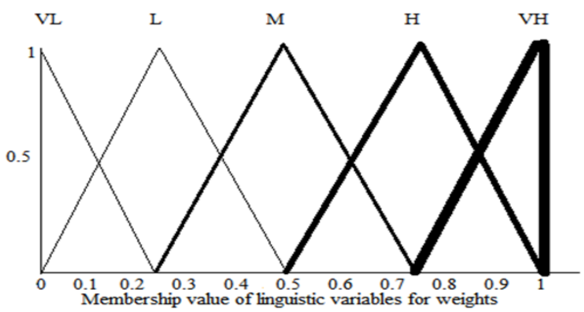

Fig. 2. Membership Value of linguistic variables

Table 2 shown below represents the linguistic variables for ratings and the figure 2 represents the membership values.

Table 2 linguistic variables for ratings

Linguistic variables for ratings

Very poor	(0,0,0.25)
Poor	(0,0.25.0.5)
Fair	(0.25,0.5,0.75)
Good	(0.5,0.75, 1)
Very Good	(0.75,1,1)

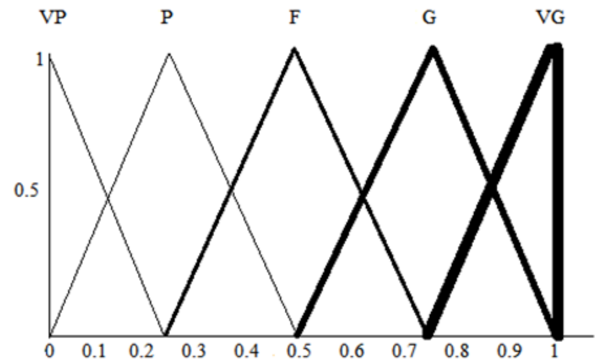

Fig. 3. linguistic weighting variables

The decision makers use these linguistic weighting variables to assess each criterion which is shown in table 3 and the fuzzy values of each criterion's importance is shown in table 4.

Table 3 Importance weight of criteria

	DM1	DM2	DM3
C1	VH	VH	VH
C2	H	M	H
C3	H	VH	H
C4	M	M	H
C5	M	H	H
C6	M	VH	H
C7	H	H	M
C8	VH	M	H
C9	M	H	M

Importance weight of criteria by three decision makers

Table 4

Importance weight of criteria in terms of fuzzy numbers

	DM1	DM2	DM3
C1	(0.75,1,1)	(0.75,1,1)	(0.75,1,1)
C2	(0.5,0.75,1)	(0.25,0.5,0.75)	(0.5,0.75,1)
C3	(0.5,0.75,1)	(0.75,1,1)	(0.5,0.75,1)
C4	(0.25,0.5,0.75)	(0.25,0.5,0.75)	(0.5,0.75,1)
C5	(0.25,0.5,0.75)	(0.5,0.75,1)	(0.5,0.75,1)
C6	(0.25,0.5,0.75)	(0.75,1,1)	(0.5,0.75,1)
C7	(0.5,0.75,1)	(0.5,0.75,1)	(0.25,0.5,0.75)
C8	(0.75,1,1)	(0.25,0.5,0.75)	(0.5,0.75,1)
C9	(0.25,0.5,0.75)	(0.5,0.75,1)	(0.25,0.5,0.75)

Next, the calculated fuzzy numbers of importance weight for each criterion by three decision makers is represented in the table 4.

Next, the ratings of alternative method with respect to each criterion by the Decision makers is shown in table 5.

Table 6
Fuzzy value for alternative 1- ocean disposal

	C1	C2	C3	C4	C5	C6	C7	C8	C9
DM1	(0.5,0.75,1)	(0.75,1,1)	(0.75,1,1)	(0.5,0.75,1)	(0,0,0.25)	(0,0.25,0.5)	(0.75,1,1)	(0,0.25,0.5)	(0.5,0.75,1)
DM2	(0.25,0.5,0.75)	(0.5,0.75,1)	(0.5,0.75,1)	(0.5,0.75,1)	(0,0.25,0.5)	(0.25,0.5,0.75)	(0.5,0.75,1)	(0,0.25,0.5)	(0.5,0.75,1)
DM3	(0.75,1,1)	(0.5,0.75,1)	(0.75,1,1)	(0.5,0.75,1)	(0,0,0.25)	(0.25,0.5,0.75)	(0.75,1,1)	(0.25,0.5,0.75)	(0.5,0.75,1)

Table 7
Fuzzy value for Alternative 2 - Landfill Disposal

	C1	C2	C3	C4	C5	C6	C7	C8	C9
DM1	(0.25,0.5,0.75)	(0.25,0.5,0.75)	(0.25,0.5,0.75)	(0,0.25,0.5)	(0.25,0.5,0.75)	(0,0.25,0.5)	(0.25,0.5,0.75)	(0.25,0.5,0.75)	(0.25,0.5,0.75)
DM2	(0.5,0.75,1)	(0.25,0.5,0.75)	(0.25,0.5,0.75)	(0.25,0.5,0.75)	(0.25,0.5,0.75)	(0.25,0.5,0.75)	(0.5,0.75,1)	(0,0.25,0.5)	(0.5,0.75,1)
DM3	(0.5,0.75,1)	(0.5,0.75,1)	(0.5,0.75,1)	(0.25,0.5,0.75)	(0.25,0.5,0.75)	(0.25,0.5,0.75)	(0.5,0.75,1)	(0.25,0.5,0.75)	(0.25,0.5,0.75)

Table 8
Fuzzy value for Alternative 3- land application

	C1	C2	C3	C4	C5	C6	C7	C8	C9
DM1	(0.75,1,1)	(0.5,0.75,1)	(0.5,0.75,1)	(0.5,0.75,1)	(0.25,0.5,0.75)	(0.75,1,1)	(0.5,0.75,1)	(0.5,0.75,1)	(0.5,0.75,1)
DM2	(0.5,0.75,1)	(0.25,0.5,0.75)	(0.5,0.75,1)	(0.5,0.75,1)	(0.5,0.75,1)	(0.5,0.75,1)	(0.75,1,1)	(0.75,1,1)	(0.5,0.75,1)
DM3	(0.5,0.75,1)	(0.25,0.5,0.75)	(0.75,1,1)	(0.5,0.75,1)	(0.75,1,1)	(0.25,0.5,0.75)	(0.5,0.75,1)	(0.75,1,1)	(0.75,1,1)

Table 9
Fuzzy value for alternative 4- processing for reutilization

	C1	C2	C3	C4	C5	C6	C7	C8	C9
DM1	(0.75,1,1)	(0.5,0.75,1)	(0.5,0.75,1)	(0.75,1,1)	(0.5,0.75,1)	(0.75,1,1)	(0.5,0.75,1)	(0.75,1,1)	(0.5,0.75,1)
DM2	(0.75,1,1)	(0.25,0.5,0.75)	(0.5,0.75,1)	(0.5,0.75,1)	(0.5,0.75,1)	(0.75,1,1)	(0.5,0.75,1)	(0.75,1,1)	(0.75,1,1)
DM3	(0.5,0.75,1)	(0.5,0.75,1)	(0.75,1,1)	(0.75,1,1)	(0.5,0.75,1)	(0.5,0.75,1)	(0.75,1,1)	(0.75,1,1)	(0.75,1,1)

And corresponding fuzzy numbers is shown in table 6.

Table 5

		C1	C2	C3	C4	C5	C6	C7	C8	C9
DM1	A1	G	VG	VG	G	VP	P	VG	P	G
	A2	F	F	F	P	F	P	F	F	F
	A3	VG	G	G	G	F	VG	G	G	G
	A4	VG	G	G	VG	G	VG	G	VG	G
DM2	A1	F	G	G	G	P	F	G	P	G
	A2	G	F	F	F	F	F	G	P	G
	A3	G	F	G	G	G	G	VG	VG	G
	A4	VG	F	G	G	G	VG	G	VG	VG
DM3	A1	VG	G	VG	G	VP	F	VG	F	G
	A2	G	G	G	F	F	F	G	F	F
	A3	G	F	VG	G	VG	F	G	VG	VG
	A4	G	G	VG	VG	G	G	VG	VG	VG

Ratings of four alternativeswith respect to each criteria determined by the decision makers

The calculated fuzzy numbers for the ratings of each alternatives with respect to the criterion by the three decision makers is shown below in table 6.

Table 6: Rating of each alternative method under each criterion in terms of fuzzy numbers

Next, the cumulative fuzzy weight of each criterion and cumulative fuzzy ratings of each criterion with respect to the alternatives is calculated and fuzzy decision matrix and fuzzy weight matrix is formed. Fuzzy weight is denoted by $\widetilde{w_J}$ and fuzzy rating is denoted by $\widetilde{x_{\iota J}}$ where k is the number of decision makers.

$$\widetilde{w_J} = (\frac{1}{k})[\widetilde{w_{J1}} \oplus \widetilde{w_{J2}} \oplus \ldots \oplus \widetilde{w_{Jk}}]$$

$$\widetilde{x_{\iota J}} = (\frac{1}{k})[\widetilde{x_{\iota J1}} \oplus \widetilde{x_{\iota J2}} \oplus \ldots \oplus \widetilde{x_{\iota Jk}}]$$

A fuzzy decision matrix is formed by the values of decision makers' opinion to get the aggregated fuzzy weight of criteria and the aggregated fuzzy ratings of alternative method. The fuzzy decision matrix $\widetilde{D}$ is

$$\widetilde{D} = \begin{bmatrix} \widetilde{x_{11}} & \widetilde{x_{12}} \cdots & \widetilde{x_{1n}} \\ \widetilde{x_{21}} & \widetilde{x_{22}} \cdots & \widetilde{x_{2n}} \\ \widetilde{x_{m1}} & \widetilde{x_{m2}} \cdots & \widetilde{x_{mn}} \end{bmatrix}$$

$$\widetilde{w} = [\widetilde{w1} \ \ \widetilde{w2} \ \ \ldots \widetilde{wn}\ ]\ , i = 1,2,\ldots,m \ for\ alternatives\ and\ j = 1,2,\ldots,n\ for\ criterion.$$

The fuzzy decision matrix and fuzzy weight matrix is calculated and shown below in table 10

Various defuzzification strategies have been suggested in literature. Here we have chosen graded mean integration approach. According to graded mean integral approach for triangular fuzzy numbers a fuzzy number $\widetilde{C} = (C1, C2, c3)$ can be transformed into crisp numbers by employing the below equation

Table 10
Fuzzy decision matrix and fuzzy weight matrix

		C1	C2	C3	C4	C5	C6	C7	C8	C9
$\widetilde{w}$		(0.75,1,1)	(0.42,0.67,0.92)	(0.58,0.83,1)	(0.33,0.58,0.83)	(0.58,0.67,0.92)	(0.58,0.75,0.92)	(0.42,0.67,0.92)	(0.50,0.75,0.92)	0.33,058,0.83)
$\widetilde{D}$	A1	(0.50,0.75,0.92)	(0.58,0.83,1)	(0.67,0.92,1)	(0.5,0.75,1)	(0,0.08,0.33)	(0.08,0.33,0.58)	(0.67,0.92,1)	(0.08,0.33,0.58)	(0.5,0.75,1)
	A2	(0.42,0.67,0.92)	(0.33,0.58,0.83)	(0.33,0.58,0.83)	(0.17,0.42,0.67)	(0.25,0.5,0.75)	(0.17,0.42,0.67)	(0.42,0.67,0.92)	(0.17,0.42,0.67)	(0.33,0.58,0.83)
	A3	(0.58,0.83,1)	(0.33,0.58,1)	(0.58,0.83,1)	(0.5,0.75,1)	(0.5,0.75,0.92)	(0.5,0.75,0.92)	(0.58,0.83,1)	(0.67,0.92,1)	(0.58,0.83,1)
	A4	(0.67,0.92,1)	(0.42,0.67,0.92)	(0.58,0.83,1)	(0.67,0.92,1)	(0.5,0.75,1)	(0.67,0.92,1)	(0.58,0.83,1)	(0.75,1,1)	(0.67,0.92,1)

$$C = \frac{C1 + 4C2 + C3}{6}$$

Crisp values of Decision matrix and weight matrix of each criterion are presented in table 11.

The best and worst values of all criterion is to be identified using

$$f_j^* = Max\ f_{ij}, j\epsilon C1\ and\ Min\ f_{ij}, J\epsilon C2\ \ , i = 1,2 \dots m$$

Table 11

Crisp Values of fuzzy decision matrix

		C1	C2	C3	C4	C5	C6	C7	C8	C9
$\tilde{w}$		0.96	0.67	0.82	0.58	0.7	0.75	0.67	0.74	0.58
	A1	0.74	0.82	0.89	0.75	0.11	0.33	0.89	0.33	0.75
$\tilde{D}$	A2	0.67	0.58	0.50	0.42	0.50	0.42	0.67	0.42	0.58
	A3	0.82	0.61	0.82	0.75	0.74	0.74	0.82	0.89	0.82
	A4	0.89	0.67	0.82	0.89	0.75	0.89	0.82	0.96	0.89

$$f_j^- = Min\ f_{ij}, j\epsilon C1\ and\ Max\ f_{ij}, J\epsilon C2\ \ , i = 1,2,..,m$$

From table 8, we get the best and worst values of all criterions.

$f_1^* = 0.96,\ f_2^* = 0.82, f_3^* = 0.89, f_4^* = 0.89, f_5^* = 0.75, f_6^* = 0.89, f_7^* = 0.89, f_8^* = 0.96, f_9^* = 0.89$

$f_1^- = 0.67,\ f_2^- = 0.58, f_3^- = 0.50, f_4^- = 0.42, f_5^- = 0.11, f_6^- = 0.33, f_7^- = 0.67, f_8^- = 0.33, f_9^- = 0.58$

Using the best and worst values find the value of S,R and Q

Compute the values of Si and Ri (i=1,2…,m) by using the relation

$$S_i = \sum_{j=1}^{n} W_j\ (f_j^* - f_{ij})/(f_j^* - f_j^-)$$

Here i=1,2…,4 and j=1,2,…,9 since we suggest four alternative method and nine criterions.

$$S_1 = 0.73 + 0 + 0 + 0.17 + 0.7 + 0.75 + 0 + 0.74 + 0.26 = 3.35$$

$$S_2 = 0.96 + 0.67 + 0.82 + 0.58 + 0.27 + 0.63 + 0.67 + 0.63 + 0.58 = 5.82$$

$$S_3 = 0.46 + 0.59 + 0.15 + 0.17 + 0.01 + 0.20 + 0.21 + 0.08 + 0.13 = 2.01$$

$$S_4 = 0.23 + 0.42 + 0.14 + 0 + 0 + 0 + 0.21 + 0 + 0 = 1.01$$

$$Compute\ R_i\ using, R_i = \max[w_j\ (f_j^* - f_{ij})/(f_j^* - f_j^-)], j = 1,2, \dots, n$$

$$R_1 = 0.75, R_2 = 0.96, R_3 = 0.59, R_4 = 0.42$$

S_i is the aggregated value of i[th] alternatives with a maximum group utility and R_i is the aggregated value of of i[th] alternatives with a minimum individual regret of opponent. W_j is the fuzzy weighted average of each criterion. Compute the values of Q_i for i=1,2..,m using S_i and R_i

$$Q_i = \frac{v(S_i - S^*)}{S^- - S^*} + \frac{(1-v)(R_i - R^*)}{(R^- - R^*)}$$

Here $S^* = \min S_i\ \ , i = 1,2..., m\ , S^- = \max S_i\ \ , i = 1,2 \dots, m,$

$and\ R^* = \min R_i\ \ , i = 1,2 \dots, m, R^* = \max R_i\ \ , i = 1,2..., m$

v is the weight for strategy of maximum group utility and usually v=0.5.

From the values of S and R, we get

$$S^* = \min S_i = 1.01$$

$$S^- = \max S_i = 5.82$$

$$R^* = \min R_i = 0.42$$

$$R^- = \max R_i = 0.96$$

$$Q_1 = 0.55, Q_2 = 1, Q_3 = 0.26, Q_4 = 0$$

The values of S, R and q are presented on the table 12.

Table 12

Values of S, R and Q

	A1	A2	A3	A4
S	3.35	5.82	2.01	1.01
R	0.75	0.96	0.59	0.42
Q	0.55	1	0.26	0

Ranking the alternative methods by sorting each S,R and Q in ascending order is shown in the table 13.

Table 13

Rank of alternative

RANK	1	2	3	4
By S	A4	A3	A1	A2
By R	A4	A3	A1	A2
By Q	A4	A2	A3	A1

This table shows that the alternative method A4 is preferred by the decision makers as it is best ranked by Q. It is clear that A4 is best ranked by both S and R.

A4 is said to be optimal compromise solution (Park et al) since it satisfies the condition

$$Q(A1) - Q(A2) \geq \frac{1}{k-1}$$

Where k is the number of alternatives and Q(A1) and Q(A2) are the first position ranking and second position ranking by Q.

A4 is said to be a stable alternative since it is best ranked by both S and R.

Therefore, the fourth alternative method, Processing for Reutilization is preferred by all the three decision makers when compared to follow other alternative method.

7. Conclusion

The objective is to help decision makers to choose the appropriate method for safe disposal of fish wastages using MCDM and fuzzy VIKOR method using linguistic data from the decision makers. Managing this huge waste is a daunting task and disposing them at the dumping yards will have an adverse effect on the environment. Hence the decision makers in the municipality office need to go for disposing methods for safe disposal of fish waste. Four alternative methods were considered for this study, Ocean Disposal, Landfill Disposal, Land application, Processing for reutilization. Three main criteria, Minimize Economic cost, Minimize Risk factors, maximize technical aspects were identified and nine sub criterions were also considered. Linguistic variables are converted to fuzzy numbers and Multi Criteria Group Decision Making by VIKOR method is followed and it is concluded that the alternative method A4 is preferred by the decision makers as it is best ranked by Q. It is clear that A4 is best ranked by both S and R.

A4 is said to be optimal compromise solution since it satisfied the necessary conditions. A4 is said to be a stable alternative since it is best ranked by both S and R. Therefore, the fourth alternative method, Processing for Reutilization is preferred by all the three decision makers.

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