

# Diagnosis of Vector-Borne Diseases Using MCDM Techniques



Kiran Pal, V. Kumar, H. D. Arora

**Abstract:** Vector -borne diseases (VBDs) are one of the major problems of human are affecting adversely to people each year in every part of the world. In this work multiple decision-making technique is used to provide a better diagnosis for VBDs. It evaluates alternative diseases having contradictory symptoms. It is very tough to exactly determine criteria weight as well as rating of alternatives (diseases) on each criterion. Here VIKOR approach is applied for medical diagnosis of VBDs such as malaria, chikungunya, and dengue, and also used the notion of intuitionistic fuzzy set (IFS) theory to explain this concept. Furthermore, criteria selected according to relevant disease and weights assigned to them by medical experts. In order to accomplish the objective, patients' data has been acquired using a questionnaire from three medical experts of Delhi region. The study shows that final outcomes are same as diagnosed by doctors regarding actual diseases as that by employing VIKOR technique based on questionnaire information. Thus, MCDM methodology can help in correct and timely diagnosis of VBDs and provides doctors a scientific diagnostic tool.

**Keywords:** Intuitionistic Fuzzy Set IFS, Intuitionistic fuzzy number (IFN), medical diagnosis, VIKOR technique,

**Nomenclature**

<i>D</i>	Doctor or medical expert
<i>IFS</i>	Intuitionistic fuzzy set
<i>IFDM</i>	Intuitionistic fuzzy decision matrix
<i>NIFD</i>	Normalized intuitionistic fuzzy difference
<i>OW</i>	Objective weight
<i>SW</i>	Subjective weight
<i>IF</i>	Intuitionistic Fuzzy
<i>IFN</i>	Intuitionistic Fuzzy number

## I. INTRODUCTION

VBDs are transmitted by mosquitoes, black flies, ticks, snails, and lice, which are having a severe threat to the human being particularly in countryside locations results in affecting the development and health of vulnerable population. The difficulty in accurate and timely diagnosis of VBDs can delay the relative treatment procedure especially in remote regions where doctors as well as hospitals are in scarce number. In this work, three major VBDs have been taken into consideration and their main symptoms have been elaborated as below:

Chikungunya resembles to dengue along with symptoms are severe joint pain also known as arthritis accompanied by high fever, rash, joint swelling, headache, muscle pain, nausea, and fatigue etc. Recently Chikungunya was reported in south-east Asia countries including India and numerous islands of Indian ocean, and in Maharashtra, it was occurred simultaneously with dengue fever. In India 48,176 chikungunya cases were reported in the year 2010 and then a decline was observed till the year 2014, but its occurrence again started rise and almost 61,330 cases were reported in the year 2017 as shown in Figure-1. In the year 2006, more than 1,500,000 instances of chikungunya were accounted in India and its side effects show up somewhere in the range of 4 and 7 days after the patient has been nibbled by the contaminated mosquito. The infection stays in the human body for 5-7 days and mosquitoes benefiting from a contaminated individual during this period can likewise become infected. Also, Chikungunya can be misdiagnosed in territories where dengue is common because it shares few clinical signs with dengue. [2]. In India, dengue is the most widely recognized mosquito-borne viral sickness and suspected mostly in patients with fever. In the year 2009, there were about 18000 cases of dengue which caused about 100 deaths and then its problem was moderate till the year 2014, but since 2015, it is on the rise again and in the year 2017, the number of dengue cases reported increased to about 1,50,000 and resulted in over 250 deaths as illustrated in Figure-2. Apart from this, as around 75% of population living in malaria-prone regions, therefore, more than 1.3 billion citizens in India are at malaria's risk. Malaria establishes itself 9-14 days after the mosquito bite and its symptoms are high fever, headache, nausea, vomiting, and muscles pain. In India, about 3 million cases of malaria were reported in the year 1995. Many control measures have been taken due to which there is a decline, however, the malaria cases reported are nearly about a million in the year 2017.

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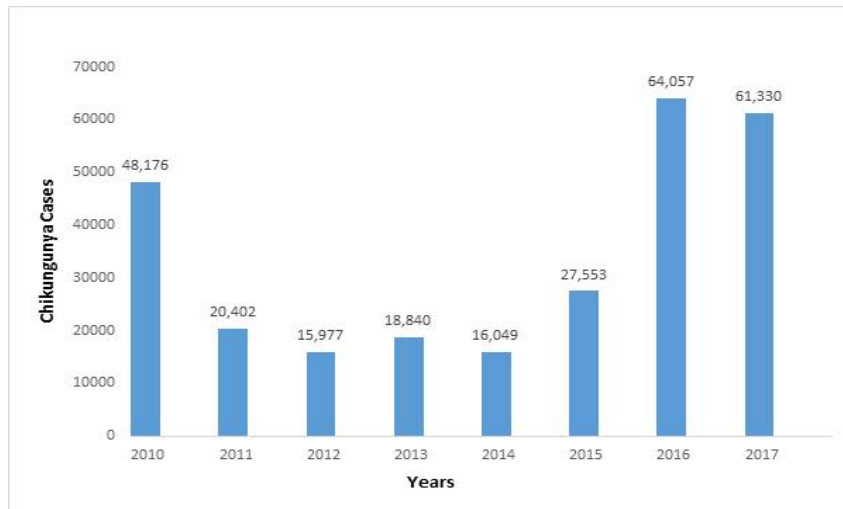
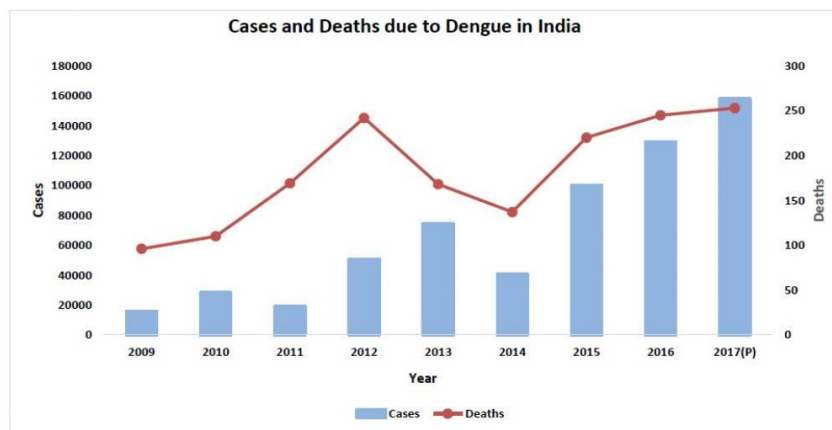


Figure 1. The Cases Of Chikungunya Reported From The Year 2010 To 2017 [1]



Source: Directorate of National Vector Borne Disease Control Programme, Dte.GHS, Ministry of Health & Family Welfare

Figure 2. Cases of Dengue in India (year 2009 to 2017) [3]

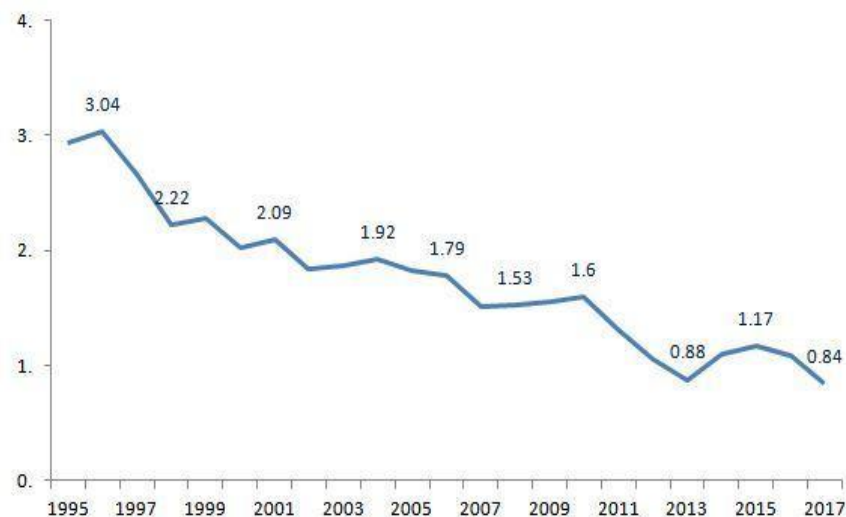


Figure 3: Cases of malaria in India (1995-2017) (in million) [4].

In previous eras, few procedures have been created so as to partially deal with such issues [8]. In any case, the majority of these methodologies center just around a single dimension, though in all actuality, medical experts have requirement of decision supporting strategies to settle on decisions by considering multiple criteria at the same time. To successfully meet clinician data requirements to

accomplish the normal patient rational patient care management use of a multi-criteria decision is preferred in priority setting [9].

Multi criteria decision making (MCDM) is an outstanding part of decision supporting tools, which comprises of a several methodologies, for instance analytic hierarchy process (AHP) [10–11], grey relational analysis (GRA) [12], technique ordered preference by similarity to the ideal solution (TOPSIS) [13], višekriterijumsko kompromisno rangiranje (VIKOR) [14] etc., and these can be utilizing in managing decision issues under the nearness of various decisions criteria. MCDM strategies are intended to help individuals settle on better decisions when they manage complex choices containing numerous dimensions. This paper deals with the implication of VIKOR method on the data provided by medical experts regarding the VBDs to differentiate the relative symptoms in accurate and quickest manner. Opricovic and Tzeng [15] presented VIKOR to make a compromise ranking from alternatives' set.

## II. PRELIMINARIES

### A. Intuitionistic Fuzzy Set (IFS) theory

#### Statement 1

Suppose a finite universal set  $X = (x_1, x_2, \dots, x_n)$  such that  $P \in X$  and P is a IFS which can be stated as [16]:

$$P = \{ \langle x, \mu_\sigma(x), \nu_\rho(x) \rangle | x \in X \} \quad (1)$$

Where  $\mu_\rho(x)$  is membership function and  $\nu_\rho(x)$  is a non-membership function, which satisfy the  $0 \leq \mu_\rho(x) + \nu_\rho(x) \leq 1$

The function  $\mu_\rho: X \rightarrow [0,1]$  and  $\nu_\rho(x): X \rightarrow [0,1]$  are the degree of membership & non-membership element X to  $P \forall x \in X$ .

Where  $\pi_\rho(x) = 1 - \mu_\rho(x) - \nu_\rho(x)$  shows the hesitancy degree of  $x \in P$ , which is the degree of hesitancy of X to P such that  $0 \leq \pi_\rho(x) \leq 1$

If  $\pi_\rho(x) = 0$  then IFS become a simple FS for an IFS.

Then the pair  $(\mu_\rho(x), \nu_\rho(x))$  is termed as IFN.

Let IFN is shown by  $\sigma = (\mu_\sigma, \nu_\sigma)$

where  $\mu_\sigma \in [0,1], \nu_\sigma \in [0,1]$  and  $\mu_\sigma + \nu_\sigma \leq 1$ .

Besides  $S(\sigma) = \mu_\sigma - \nu_\sigma$  is a score function and  $H(\sigma) = \mu_\sigma + \nu_\sigma$  is an accuracy degree of  $\sigma$ .

#### Statement 2

For any three IFNs if

$\sigma_1 = (\mu_{\sigma_1}, \nu_{\sigma_1}), \sigma_2 = (\mu_{\sigma_2}, \nu_{\sigma_2}), \sigma = (\mu_\sigma, \nu_\sigma)$  that are shown as below [23,24]:

$$(1) \sigma_1 + \sigma_2 = (\mu_{\sigma_1} + \mu_{\sigma_2} - \mu_{\sigma_1} \mu_{\sigma_2}, \nu_{\sigma_1} \nu_{\sigma_2}), \quad (2)$$

$$(2) \sigma_1 X \sigma_2 = (\mu_{\sigma_1} \mu_{\sigma_2}, \nu_{\sigma_2} - \nu_{\sigma_1} \nu_{\sigma_2}), \quad (3)$$

$$(3) \eta \sigma = (1 - (1 - \mu_\sigma)^\eta, \nu_\sigma^\eta), \eta > 0, \quad (4)$$

$$(4) \sigma^\eta = (\mu_\sigma^\eta, 1 - (1 - \nu_\sigma)^\eta), \eta > 0. \quad (5)$$

#### Statement 3

Now suppose any two IFNs and then score function and accuracy function can be present as follows [17]:

$$\text{If } S(\sigma_1) < S(\sigma_2), \text{ then } \sigma_1 < \sigma_2; \quad (6)$$

$$\text{If } S(\sigma_1) = S(\sigma_2) \quad (7)$$

$$\text{If } H(\sigma_1) < H(\sigma_2), \text{ then } \sigma_1 < \sigma_2; \quad (8)$$

$$\text{If } H(\sigma_1) = H(\sigma_2), \text{ then } \sigma_1 = \sigma_2 \quad (9)$$

#### Statement 4

Suppose X is the universal set and let P, Q  $\in$  IFS (X) can be expressed by:

$$P = \{ \langle \tau_i, \mu_s(\tau_i), \nu_s(\tau_i) | \tau_i \in X \rangle \}, \text{ and}$$

$$Q = \{ \langle \tau_i, \mu_T(\tau_i), \nu_T(\tau_i) | \tau_i \in X \rangle \} \quad (10)$$

Let E is an entropy, which is a real valued function such that IFS(X)  $\rightarrow$  [0,1] can satisfy these property [18]: -

$$(1) E(P) = 1 \text{ if } \mu_p(x_i) = \nu_p(x_i) \text{ for } \forall x \in X. \quad (11)$$

$$(2) E(P) = 0 \text{ if p is crisp set, i.e. } \mu_p(x_i) = 0, \nu_p(x_i) = 1 \text{ or } \mu_p(x_i) = 1, \nu_p(x_i) = 0, \forall x_i \in X. \quad (12)$$

$$(3) E(P) \leq E(Q) \text{ if } P \subseteq Q. \quad (13)$$

$$(4) E(P) = E(Q) \quad (14)$$

#### Statement 5

As we know  $\sigma_1 = (\mu_{\sigma_1}, \nu_{\sigma_1})$  and  $\sigma_2 = (\mu_{\sigma_2}, \nu_{\sigma_2})$  are two IFNs.

Then the distance between  $\sigma_1$  and  $\sigma_2$  can be calculated by [27]:

$$\Omega(\sigma_1, \sigma_2) = \frac{|\mu_{\sigma_1} - \mu_{\sigma_2}| + |\nu_{\sigma_1} - \nu_{\sigma_2}|}{4} + \frac{\text{Max}(|\mu_{\sigma_1} - \mu_{\sigma_2}|, |\nu_{\sigma_1} - \nu_{\sigma_2}|)}{2} \quad (15)$$

#### Statement 6

Now let the collection of IFNs  $\sigma_i = (\mu_{\sigma_i}, \nu_{\sigma_i})$

,  $i = 1, 2, 3, \dots, n, W = (w_1, w_2, w_3, \dots, w_n)^T$  known as weight vector of  $\alpha_i$ .

where  $i = 1, 2, \dots, n$  expressed as  $\omega_i \in [0,1]$  and  $\sum_{i=1}^n w_i = 1$ , if SIFWA:  $V_n \rightarrow V$  and

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$$SIFWA(\sigma_1, \sigma_2, \sigma_3, \dots, \sigma_n) = w_1\sigma_1 + w_2\sigma_2 + w_3\sigma_3 + \dots + w_n\sigma_n = \left( \frac{\prod_{i=1}^n \mu_{\sigma_i}^{w_i} \prod_{i=1}^n v_{\sigma_i}^{w_i}}{\prod_{i=1}^n (\mu_{\sigma_i}^{w_i} + \prod_{i=1}^n (1-\mu_{\sigma_i})^{w_i}) \prod_{i=1}^n (v_{\sigma_i}^{w_i} + \prod_{i=1}^n (1-v_{\sigma_i})^{w_i})} \right) \quad (16)$$

where SIFWA function known as symmetric IF weighted average operator [19].

### B. Verbal (Linguistic) variables

The Verbal/linguistic variables play an important tool where situations are very critical or complex [20]. In this analysis, rating of alternative and relative weight regarding each criterion are assumed as intuitionistic terms, which are expressed by using IFNs. It is important to mention here that IFNs sets are defined on the basis of theoretical data or questioner, which has been given by various expert of their field.

### C. The OW method

The concept of entropy [31] is useful measure of uncertainty information, which is derived through the probability theory. It can be used to know relative differences in intensities of criterion to mean internal information sent to decision maker, then, we use nonrealistic discrimination in various data to have vital weights in the entropy method of alternative criteria [21]. Vlachos and Sergiadis [22] demonstrates a methodology for IFS to measure entropy on the basis of information theory, which is given as under:

$$E(P) = -\frac{1}{n \ln 2} \sum_{i=1}^n [\mu_p(x_i) + v_p(x_i) \ln v_p(x_i) - (1 - \pi_p(x_i)) - \pi_p(x_i) \ln 2] \quad (17)$$

Where  $\mu_p(x_i) = 0, v_p(x_i) = 1, \pi_p(x_i) = 1$  then  $\mu_p(x_i) \ln \mu_p(x_i) = 0, v_p(x_i) \ln v_p(x_i) = 0$  and  $1 - \pi_p(x_i) \ln 1 - \pi_p(x_i) = 0$

In this paper, IFE measure has been used to evaluate the OW for disease choosing criteria, and the method is clarified stepwise as under:

Let  $m$  alternatives are present here such as  $P_i$  ( $i=1,2, \dots, m$ ) to be accomplished over  $n$  criteria

&  $S_i$  ( $i=1,2, \dots, n$ ).

Now the IFDM can be formed as:

$$R = \begin{pmatrix} r_{11} & r_{12} & \dots & r_{1n} \\ r_{21} & r_{22} & \dots & r_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ r_{m1} & r_{m2} & \dots & r_{mn} \end{pmatrix} \quad (18)$$

Where  $r_{ij} = (\mu_{ij}, v_{ij})$ ,

$i=1,2, \dots, m$  &  $j=1,2, \dots, n$

**Stage 2:** Evaluate the IFE.

The subsequent expression is used to evaluate IFE:

$$E(P) = -\frac{1}{n \ln 2} \sum_{i=1}^n [\mu_p(x_i) + v_p(x_i) \ln v_p(x_i) - (1 - \pi_p(x_i)) - \pi_p(x_i) \ln 2] \quad (19)$$

where  $j=1,2,3, \dots, n$

**Stage 3:** Evaluate OW of criteria by:

$$\omega_j^o = \frac{1 - E_j}{\sum_{j=1}^n (1 - E_j)}, \quad j=1,2,3, \dots, n \quad (20)$$

where  $0 \leq w_j^o \leq 1$  and  $n \sum_{j=1}^n w_j^o = 1$

**Table- I: Verbal (Linguistic) terms for alternatives' and criteria's rating**

Verbal terms IFNs	
Poor (P)	(0.05, 0.90)
Fair (F)	(0.50, 0.50)
Strong (S)	(0.80, 0.10)
Very Strong (VS)	(0.90, 0.05)

### D. The Proposed Disease Detection Method

To deal with an opinion provider assortment difficulty, the judgement taker should assess alternatives relating to every criterion, address criteria loads, & also determine the ideal one from produced set of options. This area covers VIKOR technique to the IFS for disease choosing and a combination weighting strategy is exploited for allocating the loads of calculation criteria. In this strategy, choices' ratings are assumed as linguistic terms that has been described by IFNs as listed in Table 1. The criteria's subjective loads are assessed by therapeutic medical expert with verbal value appeared in Table 1. The criteria's OWs are accomplished by utilizing IFE path, thusly, suggested IF VIKOR technique can be profited by IFSs just as combine the characteristics of two sorts of weighting strategies. Let a disease is chosen by medicinal specialists (doctors)  $DM_k$  ( $k=1,2, \dots, z$ ),  $m$  alternatives (diseases),  $F_i$  ( $i=1,2, \dots, m$ ), & symptoms  $S_j$  ( $j=1,2,3, \dots, n$ ). Every therapeutic specialist is specified with a weight  $\eta_k > 0$  ( $k=1,2, \dots, z$ ,  $\sum_{k=1}^z \eta_k = 1$ ) to reflect his/her relative significance in ailment choosing process.

Stages of purposed IF VIKOR technique for diseases' ranking are evaluated as given below:

**Stage 1:** In order to get collective opinion, find the average of individual opinion of medical expert.

In the disease choosing process, the medical expert's individual opinions should be aggregated into gathering assessment ascertain a collective IFDM.

Suppose  $r_{ij}^k = (\mu_{ij}^k, v_{ij}^k)$  be the IFN specified by  $DM_k$  on evaluation of  $F_i$  regarding  $S_i$ .

Now the aggregated IF rating ( $r_{ij}$ ) of diseases regarding each symptom can be evaluated with the help of SIFWA operator as:

$$r_{ij} = SIFWA(r_{ij}^1, r_{ij}^2, \dots, r_{ij}^l) = \sum_{k=1}^l \eta_k r_{ij}^k = \left( \frac{\prod_{k=1}^l (\mu_{ij}^k)^{\eta_k}}{\prod_{k=1}^l (\mu_{ij}^k)^{\eta_k} + \prod_{k=1}^l (1 - \mu_{ij}^k)^{\eta_k}}, \frac{\prod_{k=1}^l (v_{ij}^k)^{\eta_k}}{\prod_{k=1}^l (v_{ij}^k)^{\eta_k} + \prod_{k=1}^l (1 - v_{ij}^k)^{\eta_k}} \right) \quad (21)$$

Thus, we can show disease detection problem in matrix form as follows.

$$R = \begin{pmatrix} r_{11} & r_{12} & \dots & r_{1n} \\ r_{21} & r_{22} & \dots & r_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ r_{m1} & r_{m2} & \dots & r_{mn} \end{pmatrix} \quad (22)$$

where  $r_{ij} = (\mu_{ij}, v_{ij})$ ,  $i=1,2,\dots,m$ , &  $j=1,2,\dots,n$  are linguistic terms that are described in IFNs.

**Stage 2:** Evaluated criteria's SWs

Let the weight of criteria (symptoms)  $S_j$  is given as  $\omega_j^k = (\mu_j^k, v_j^k)$  by the medical experts  $DM_k$ . Therefore, the collective IF weight of the criteria (symptoms) has been calculated by the SIFWA operator.

$$r_{\bar{j}} = SIFWA(r_{\bar{j}}^1, r_{\bar{j}}^2, \dots, r_{\bar{j}}^l) = \sum_{k=1}^l \eta_k r_{\bar{j}}^k = \left( \frac{\prod_{k=1}^l (\mu_j^k)^{\eta_k}}{\prod_{k=1}^l (\mu_j^k)^{\eta_k} + \prod_{k=1}^l (1 - \mu_j^k)^{\eta_k}}, \frac{\prod_{k=1}^l (v_j^k)^{\eta_k}}{\prod_{k=1}^l (v_j^k)^{\eta_k} + \prod_{k=1}^l (1 - v_j^k)^{\eta_k}} \right) \quad (23)$$

where  $\omega_j = (\mu_j, v_j)$ ,  $j=1,2,\dots,n$  is a important weight of  $j$ th criterion.

By using criteria's collective weights  $\omega_i$ , the normalized SW of each criterion can be calculated by the expression [35,36]:

$$w_j' = \frac{\mu_j + \pi_j \left( \frac{\mu_j}{\mu_j + v_j} \right)}{\sum_{j=1}^n \left( \mu_j + \pi_j \left( \frac{\mu_j}{\mu_j + v_j} \right) \right)}, j = 1, 2, \dots, n, \quad (24)$$

where  $\pi_j = 1 - \mu_j - v_j$  and  $\sum_{j=1}^n \omega_j^s = 1$

**Stage 3:** Evaluate criteria's OWs by:

The criteria's OW can be evaluated by employing the OW technique that has been expressed as under:

$$\sum_{j=1}^n w_j^0 = 1. \quad (25)$$

**Stage 4:** calculate IF positive and negative ideal solution (best)  $\psi_j^* = (\mu_j^*, v_j^*)$  and  $\psi_j^- = (\mu_j^-, v_j^-)$ , respectively of all criteria that has been specified below:

$$\psi_j^* = \begin{cases} \max r_{ij}, & \text{for benefit criteria} \\ \min r_{ij}, & \text{for cost criteria} \end{cases}, j = 1, 2, 3, \dots, n \quad (26)$$

$$\psi_j^- = \begin{cases} \max r_{ij}, & \text{for benefit criteria} \\ \min r_{ij}, & \text{for cost criteria} \end{cases}, j = 1, 2, 3, \dots, n \quad (27)$$

**Stage 5:** evaluated NIFDs  $\Omega_{ij}$ ,  $i=1,2,\dots,m$  and  $j=1,2, \dots,n$ . Now NIFDs  $\Omega_{ij}$  has been calculated as:

$$(28)$$

where

$$\Omega(\Psi_j^*, r_{ij}) = \frac{|\mu_j^* - \mu_j^-| + |v_j^* - v_j^-|}{4} + \frac{\max(|\mu_j^* - \mu_j^-|, |v_j^* - v_j^-|)}{2} \quad (29)$$

$$\Omega(\Psi^*, \Psi^-) = \frac{|\mu_j^* - \mu_j^-| + |v_j^* - v_j^-|}{4} + \frac{\max(|\mu_j^* - \mu_j^-|, |v_j^* - v_j^-|)}{2} \quad (30)$$

**Stage 6:** calculate the entities such as  $R_i$  and  $S_i$ ,  $i=1,2,\dots,m$  with the help of the expression as shown below:

$$S_i = \phi \sum_{j=1}^n w_j' \bar{\Omega}_{ij} + (1 - \phi) \sum_{j=1}^n w_j^q \bar{\Omega}_{ij} = \sum_{j=1}^n [\phi w_j' + (1 - \phi) w_j^q] \bar{\Omega}_{ij} = \sum_{j=1}^n w_j^l \bar{\Omega}_{ij}, \quad (31)$$

$$R_i = \max_j (w_j^c \bar{\Omega}_{ij}). \quad (32)$$

where  $w_j^l = \phi w_j' + (1 - \phi) w_j^q$  is the criteria's combination weights.

Now  $\emptyset \in [0,1]$  defined by the relative importance amongst the SWs and OWs, and  $\emptyset = 0.5$  has been considered for easily computations.

**Stage 7:** compute value  $Q_i$ ,  $i=1,2,\dots,m$  by the expression

$$Q_i = v \frac{S_i - S^*}{S^- - S^*} + (1 - v) \frac{R_i - R^*}{R^- - R^*} \quad (33)$$

$$S^* = \min_i S_i, S^- = \max_i S_i, R^* = \min_i R_i, R^- = \max_i R_i, \quad (34)$$

Where  $1 - v$  and  $v$  are weights for the individual regret and strategy of maximum group utility, respectively. The  $v$  value can be considered as 0.5 (generally).



**Stage 8:** to find the rank of alternative (diseases) with the help of the values S, R, & Q in ascending order.

**Stage 9:** Recommend a compromise arrangement, disease (F) is best positioned by measure Q (lowest) if accompanying two conditions have been fulfilled:

**C1.** Acceptable advantage:

$$Q F^{(2)} - Q F^{(1)} \geq 1/(m - 1) \tag{35}$$

where  $F^{(2)}$  is alternative with second place in positioning list by Q.

**C2.** Acceptable stability: Alternative  $F^{(1)}$  should be in initial place by S or/and R, and it should also be unchanging within a process of decision-making that could be “voting by majority rule” (when  $v > 0.5$  is required), or “by consensus”  $v \approx 0.5$ , or “with veto” ( $v < 0.5$ ).

Noted that if one of the above conditions is not fulfilled, the following compromise solutions can be suggested:

Firstly, if only **C2** is not fulfilled, Alternatives  $F^{(1)}$  and  $F^{(2)}$  has been employed and Secondly, if **C1** is not fulfilled, alternatives  $F^{(1)}, F^{(2)}, \dots, F^{(M)}$

Where  $F^{(M)}$  can be calculated by the equation

$$Q F^{(M)} - Q F^{(1)} < 1/(m - 1) \text{ for highest } M. \tag{36}$$

**III. CASE STUDY**

So as to demonstrate the effectiveness of suggested IFH-VIKOR technique for diseases diagnosis and detection, a practical case study on disease diagnosis is considered here:

**A. Disease diagnosis by medical expert in the hospital**

Let there are four patients p1001, p1002, p1003, p1004 in a hospital at Delhi who are suffering from different type of fever due to mosquitos’ bite. Medical experts need to diagnosis the disease. Let us consider disease F1 (chikungunya), F2 (dengue), F3(malaria) as alternatives with seven criteria, which include S1 (fever), S2 (joint pain), S3 (chills and rigors), S4 (body rash), S5 (retro orbital head ache), S6 (muscle pain/body pain), S7 (vomiting/nausea) for further assignment. To perform the evaluation of appropriate disease, a committee of three medical experts ME1, ME2, and ME3 has been established. The committee of medical experts has given their opinion in the form of linguistic terms as listed in Table I. Criteria weights for all three disease are presented in Table II(a) and weightage according to the symptoms of particular patient diagnosed by doctors as shown in Table II(b). In detection procedure of disease, accompanying weights are allocated to three medicinal specialists:  $\lambda_1 = 0.20$ ,  $\lambda_2 = 0.35$ , and  $\lambda_3 = 0.45$  on the basis of distinctive domain knowledge, background, & expertise.

**Table- II(a) : Symptom’s weight assigned by three experts for each disease**

Symptoms	Dengue			Chikungunya			Malaria		
	ME <sub>1</sub>	ME <sub>2</sub>	ME <sub>3</sub>	ME <sub>1</sub>	ME <sub>2</sub>	ME <sub>3</sub>	ME <sub>1</sub>	ME <sub>2</sub>	ME <sub>3</sub>
S <sub>1</sub>	VS	VS	VS	S	S	S	S	S	S
S <sub>2</sub>	S	S	S	VS	VS	VS	P	P	P
S <sub>3</sub>	P	P	P	P	P	P	VS	VS	VS
S <sub>4</sub>	S	S	S	S	F	S	P	P	P
S <sub>5</sub>	VS	VS	VS	P	P	P	P	P	P
S <sub>6</sub>	S	S	S	P	P	P	F	P	F
S <sub>7</sub>	P	P	P	P	P	F	P	F	S

**Table- II(b): Linguistic opinion of three experts for patient ‘p101’**

Symptoms (S)	Medical expert (D)	Diseases		
		F <sub>1</sub> (Chikungunya)	F <sub>2</sub> (Dengue)	F <sub>3</sub> (Malaria)
S <sub>1</sub>	D <sub>1</sub>	F	F	VS
	D <sub>2</sub>	P	F	VS
	D <sub>3</sub>	P	P	S
S <sub>2</sub>	D <sub>1</sub>	P	P	P
	D <sub>2</sub>	P	F	P
	D <sub>3</sub>	F	F	P
S <sub>3</sub>	D <sub>1</sub>	P	P	VS
	D <sub>2</sub>	P	P	VS
	D <sub>3</sub>	F	P	S

S <sub>4</sub>	D <sub>1</sub>	P	P	VS
	D <sub>2</sub>	P	P	VS
	D <sub>3</sub>	F	P	VS
S <sub>5</sub>	D <sub>1</sub>	S	P	S
	D <sub>2</sub>	S	P	S
	D <sub>3</sub>	VS	F	VS
S <sub>6</sub>	D <sub>1</sub>	P	F	S
	D <sub>2</sub>	F	S	F
	D <sub>3</sub>	VS	VS	F
S <sub>7</sub>	D <sub>1</sub>	P	P	P
	D <sub>2</sub>	S	F	F
	D <sub>3</sub>	S	F	S

Next, this technique has been recommended to give a problem's solution of disease detection, and computational procedure has been discussed as under:

**Stage 1:** We create consolidated IFDM by exploiting SIFWA operator as specified in Equation (21) after quantifying linguistic estimations as corresponding to IFNs. Relative outcomes have been revealed in Table IV(a).

**Stage 2:** Evaluation of medicinal experts on criteria weights has been possible by utilizing the Equation (23) as registered in Table IV(a). Also, Table III(a) collective weightage of each criteria for relevant disease. Then, normalized SWs of criteria have been acquired through the help of Equation (24) as showed in Table IV(b).

**Stage 3:** Each criterion's IFE value has been attained by Equation (19) based on the OW method and the criteria's OWs

have been computed by using Equation (20) and Table V(a) lists the outcomes of these calculations.

**Stage 4:** S<sub>1</sub> to S<sub>6</sub> are chosen as benefit criteria whereas S<sub>7</sub> is considered as cost criterion. In this manner, we decide the IF positive and negative ideal solution of all criteria

ratings as observed beneath:

$$f_1^* = (.86,.07), f_2^* = (.36,.61), f_3^* = (.86,.07), f_4^* = (.90,.05),$$

$$f_5^* = (.85,.07), f_6^* = (.81,.11), f_7^* = (.36,.61)$$

$$f_1^- = (.09,.85), f_2^- = (.05,.90), f_3^- = (.05,.90), f_4^- = (.05,.90),$$

$$f_5^- = (.17,.77), f_6^- = (.57,.39), f_7^- = (.51,.37)$$

**Stage 5:** By using the Equation (28), we can calculate the NIFDs as shown in Table 4(b).

**Stage 6:** Now S, R, and Q values are computed by Equations (31) to (33) for 3 alternatives, which have been displayed in Table 5(b).

**Stage 7:** Rankings of 4 alternatives by S, R, and Q values in the ascending order have been presented in Table 5(c).

**Stage 8:** On the basis of Table 5(b) the ranking of the three alternatives is  $F_3 > F_1 > F_2$  in accordance with the Q value. Consequently, F<sub>3</sub> is the most suitable disease diagnosis among the others available disease.

**Table- III(a): Collective weightage of each criteria for relevant disease**

Diseases	S <sub>1</sub>	S <sub>2</sub>	S <sub>3</sub>	S <sub>4</sub>	S <sub>5</sub>	S <sub>6</sub>	S <sub>7</sub>
F <sub>1</sub>	(.09,.85)	(.17,.77)	(.17,.77)	(.17,.77)	(.85,.07)	(.60,.29)	(.36,.37)
F <sub>2</sub>	(.21,.73)	(.36,.61)	(.05,.90)	(.05,.90)	(.17,.77)	(.81,.11)	(.36,.61)
F <sub>3</sub>	(.86,.07)	(.05,.90)	(.86,.07)	(.90,.05)	(.85,.07)	(.57,.39)	(.51,.37)
w <sub>i</sub>	(.9,.05)	(.8,.1)	(.05,.9)	(.8,.1)	(.9,.05)	(.8,0.1)	(.1653,.77)

**Table- IV (a): SWs of disease and aggregated IFDM**

Diseases	S <sub>1</sub>	S <sub>2</sub>	S <sub>3</sub>	S <sub>4</sub>	S <sub>5</sub>	S <sub>6</sub>	S <sub>7</sub>
F <sub>1</sub>	(0.71,0.1)	(0.74,0.1)	(0.05,0.9)	(0.84,0.08)	(0.5,0.5)	(0.21,0.73)	(0.05,0.9)
F <sub>2</sub>	(0.87,0.06)	(0.85,0.07)	(0.9,0.05)	(0.86,0.07)	(0.86,0.07)	(0.85,0.07)	(0.2,0.56)
F <sub>3</sub>	(0.65,0.27)	(0.20,0.72)	(0.05,0.9)	(0.05,0.9)	(0.06,0.87)	(0.13,0.81)	(0.5,0.5)
w <sub>i</sub>	(.80,.10)	(.90,.05)	(.05,.90)	(.71,.19)	(.05,.65)	(.05,.47)	(.17,.77)

**Table- IV 4(b): Normalized SWs of criteria and NIFDs**

Diseases	S <sub>1</sub>	S <sub>2</sub>	S <sub>3</sub>	S <sub>4</sub>	S <sub>5</sub>	S <sub>6</sub>	S <sub>7</sub>
F <sub>1</sub>	1	.5984	.8455	.8559	0	.75	.8276
F <sub>2</sub>	.8457	0	1	1	1	0	0
F <sub>3</sub>	1	1	1	1	1	1	1
w <sup>s</sup> <sub>i</sub>	.2944	.3138	.0174	.2604	.0237	.0318	.0585

## Diagnosis of Vector-Borne Diseases using MCDM Techniques

**Table- V(a): OWs of diseases and evaluated IFE values**

Weights	S <sub>1</sub>	S <sub>2</sub>	S <sub>3</sub>	S <sub>4</sub>	S <sub>5</sub>	S <sub>6</sub>	S <sub>7</sub>
<i>E<sub>i</sub></i>	.5656	0.6622	0.4873	0.4554	0.5251	.8206	.9789
<i>w<sup>o</sup><sub>i</sub></i>	.1734	.1349	.2047	.2174	.1896	.0716	.0084

**Table- V(b): S, R, and Q values for three diseases**

Indexes	F <sub>1</sub>	F <sub>2</sub>	F <sub>3</sub>
<b>S</b>	.7330	.6544	.3095
<b>R</b>	.2339	.2389	.2243
<b>Q</b>	.8291	.9072	0

**Table- V(c): Ranking of three alternatives by S, R, and Q**

Indexes	F <sub>1</sub>	F <sub>2</sub>	F <sub>3</sub>
<b>S</b>	3	2	1
<b>R</b>	3	2	1
<b>Q</b>	2	3	1

**Table- VI: Ranking and disease diagnosis in the patients as below:**

Patient	Ranking by VIKOR	Disease
p1001	F <sub>3</sub> > F <sub>1</sub> > F <sub>2</sub>	Malaria
p1002	F <sub>1</sub> > F <sub>2</sub> > F <sub>3</sub>	Chikungunya
p1003	F <sub>2</sub> > F <sub>1</sub> > F <sub>3</sub>	Dengue
p1004	F <sub>1</sub> > F <sub>3</sub> > F <sub>2</sub>	Chikungunya

### III. RESULTS AND DISCUSSION

The three alternatives are ranked as  $F_3 > F_1 > F_2$  as shown in table V (b) and finally patient p1001 has been diagnosed with malaria. This proves the confirmation of our suggested technique. As per Table V(c), ranking of three diseases based on the value of Q. Likewise, for the other three patients, same process has been applied and evaluated, the results are summarized in Table VI. Thus, it is obvious that by VIKOR method, patients i.e. p1002 and p1004 are suffer from chikungunya, whereas, p1001 and p1003 are facing malaria and Dengue, respectively.

### IV. CONCLUSION

This paper deals with the IF VIKOR approach to manage with disease chosen problems in which alternatives' preference ratings and symptoms' importance are considered as linguistics terms described by IFNs. The collective assessment of experts' rating was aggregated by using SIFWA operator. For the disease evaluation and detection, both SWs and OWs were assumed that can circumvent the subjectivity in the knowledge of experts and also helpful in reflecting the necessary characteristics of a disease detection difficulty. In this way, VIKOR approach for medical diagnosis is studied and the concept is generalized by the application of IFS theory. On the basis of closeness to ideal solution, VIKOR method helps us to introduce ranking index. However, this study is limited to only four patients' medical data but a better and more precise results could be obtained if following points such as large number of patients' data and more alternatives as well as criteria will be taken into consideration.

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### REFERENCE

1. The resurgence of chikungunya in India: How should we tackle it? Available at
2. <https://www.ideasforindia.in/topics/governance/the-resurgence-of-chikungunya-in-india-how-should-we-tackle-it.html> accessed June 2019
3. Chikungunya. Available at [https://www.who.int/denguecontrol/arbo-viral/other\\_arboviral\\_chikungunya/en/](https://www.who.int/denguecontrol/arbo-viral/other_arboviral_chikungunya/en/) accessed 14 June 2019.
4. Number of dengue cases in 2017 was the highest in a decade. Available at
5. <https://www.downtoearth.org.in/news/health/number-of-dengue-cases-in-2017-was-the-highest-in-a-decade-60982> accessed 14 June 2019.
6. A. Majumder. Cases of malaria in India (1995-2017) (in mil.). Available at <https://www.projectguru.in/publications/government-india-curbing-malarial-prevalence/1-621/> accessed June 2019.
7. A.E. Kazdin. Evidence-based treatment and practice: new opportunities to bridge clinical research and practice, enhance the knowledge base, and improve patient care. *Am. Psychol.* 2008; 63, 146–159.
8. NK Choudhry, RH Fletcher and SB Soumerai, Systematic review: the relationship between clinical experience and quality of health care. *Ann. Intern. Med.* 2005; 142, 260–273.
9. KB Waghlikar, V Sundararajan and AW Deshpande, Modeling paradigms for medical diagnostic decision support: a survey and future directions. *J. Med. Syst.* 2012; 36, 3029–3049.
10. JPA Ioannidis and AM Garber, Individualized cost effectiveness analysis. *Plos. Med.* 2011; 8, 1001058.



11. JG Dolan, Multi-criteria clinical decision support: a primer on the use of multiple criteria decision making methods to promote evidence-based, patient-centered health care. *Patient* 2010; 3, 229–248.
12. CW Lee and NK Kwak, Strategic enterprise resource planning in a health-care system using a multicriteria decision-making model. *J. Med. Syst.* 2011; 35, 265–275.
13. S Ajami and S Ketabi, Performance evaluation of medical records departments by analytical hierarchy process (AHP) approach in the selected hospitals in Isfahan. *J. Med. Syst.* 2012; 36, 1163–1171.
14. JL Deng, Control problems of grey systems. *Syst. Control. Lett.* 1982; 1, 288–294.
15. YJ Lai, TY Liu and CL Hwang, TOPSIS for MODM. *Eur. J. Oper. Res.* 1994; 76, 486–500.
16. S Opricovic, Multicriteria Optimization of Civil Engineering Systems. PhD Thesis. Faculty of Civil Engineering. Belgrade, 1998, 1-302.
17. S Opricovic and G-H Tzeng, Compromise solution by MCDM methods: A comparative analysis of VIKOR and TOPSIS. *European journal of operational research.* 2004; 156, 445–455.
18. K Atanassov, Intuitionistic fuzzy sets. *Fuzzy Sets Syst.* 1986; 20, 87–96.
19. ZS Xu, Intuitionistic fuzzy aggregation operators. *IEEE Trans. Fuzzy Syst.* 2007; 15, 1179–1187.
20. E Szmidi and J Kacprzyk, Using intuitionistic fuzzy sets in group decision-making. *Control Cybern.* 2002; 31, 1037-1054.
21. MM Xia and ZS Xu, Entropy/cross entropy-based group decision making under intuitionistic fuzzy environment. *Inf. Fusion* 2012; 13, 31–47.
22. LA Zadeh, The concept of a linguistic variable and its application to approximate reasoning—I. *Inf. Sci.* 1975; 8, 199–249.
23. CE Shannon and W Weaver, *A Mathematical Theory of Communication.* The University of Illinois Press: Urbana, IL, USA, 1947.
24. IK Vlachos and GD Sergiadis, Intuitionistic fuzzy information-Applications to pattern recognition. *Pattern. Recogn. Lett.* 2007; 28, 197–206.

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