Application of TOPSIS in the Diagnosis of Vector Borne Diseases

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Abstract: “Intuitionistic Fuzzy Set” (IFS) is used to manage nebulosity and indecision. In current investigation, another intuitionistic fuzzy TOPSIS method is proposed for decision making by utilizing entropy weight. Current model permits estimating the degree of membership and non-membership of various alternatives assessed over a criterion set. A case study has been carried out to diagnosis of vector borne disease. Criteria’s have been selected according to relevant disease and weight has been assigned to them by medical expert’s committee. It has been established that TOPSIS method can diagnose the VBD diseases using specific symptoms as criteria and VBDs as alternatives. The suggested methodology can help in correct and timely diagnosis of VBDs and provides doctors an innovative diagnostic tool (WHO, 2004; WHO, 2014). The result is validated by applying fuzzy VIKOR method.

Keywords: Entropy, IFS, MCDM, TOPSIS, SIFWA operator.

Nomenclature

W  Weight vector
CC  Closeness coefficient
IFDM  Intuitionistic fuzzy decision matrix
IF  Intuitionistic fuzzy
DOD  Degree of divergence
MCDM  Multiple criteria decision making
WFDM  weighted fuzzy decision matrix

1. INTRODUCTION

Mosquito also known as vectors has an ability to produce serious diseases in human or animal populations as they can spread pathogens and parasites. With respect to south-east Asia region, common vector-borne diseases (VBD) types are chikungunya, dengue, and malaria etc. Chikungunya resembles to dengue along with symptoms of severe joint pain also known as arthritis accompanied by high fever, rash, joint swelling, headache, muscle pain, nausea, and fatigue etc. It establishes itself in 9-14 days after the mosquito bite and its symptoms are high fever, headache, nausea, vomiting, and muscles pain. Symptoms of dengue are high fever, pain behind the eyes, head ache, body aches and joint pain, and skin rash. Symptoms of Malaria are high fever, headache, nausea, vomiting, and muscles pain.

Figure 1 shows the rising cases of chikungunya, dengue, and malaria in Delhi and an indication of severity of the problem. To control these VBD, WHO recommended some instructions such as to provide moral and technical support as well as new tools and innovative diagnosis should be developed to further fortify this effort.

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In the world, one sixth of illness and disability endured is because of VBD, with more than half of population right now evaluated to be in danger of these infections. VBD are transmitted by mosquitoes, black flies, ticks, snails, and lice etc. The difficulty in accurate and timely diagnosis of VBD can delay the relative treatment procedure especially in remote regions where doctors as well as hospitals are in scarce number. MCDM methodologies have been useful to engineering, management, economics, and so forth. Hwang and Yoon (1981) first developed the traditional MCDM approach like TOPSIS, this method has benefits like simple, rationally comprehensible concept, computational efficiency is good, capability of measuring the relative performance for every alternative (Yeh, 2002).

Figure 1 Spiralling Chikungunya and Malaria cases in Delhi

(Source: The Times of India August 15, 2017)

Zadeh (1965) introduced the fuzzy sets theory in year 1965, which can assign a single membership value to each element amongst zero and one, then Gau and Buecher (1993) proposed vague set concept. Bustince and Burillo (1996) shown that vague set coincides with IFSs. Kakushadze et al. (2017) assessed the savings in treatment cost from early diagnosis of cancer and found that annual savings was in 11 digits for U.S. nationals. Hung and Chen (2009) suggested a new fuzzy TOPSIS model by utilizing entropy weights. Balioti et al. (2018) used MCDM and TOPSIS in the selection of spillway for a dam in Greece. In another study, Vahdani et al. (2011) proposed fuzzy modified TOPSIS for manufacturing decisions regarding the selection of robot and rapid prototyping process.
II. PRELIMINARIES

2.1. IFS theory

Statement 1 (Atanassov, 1986).
An IFS B is subset of an universe of discourse X can be expressed as: \( B = \{ (x, \mu_B(x), \nu_B(x)) \} \), \( \mu_B : X \rightarrow [0,1] \) and \( \nu_B : X \rightarrow [0,1] \) such that \( 0 \leq \mu_B(x) + \nu_B(x) \leq 1, \forall x \) with this property \( \nu_B(x) = 1 - \mu_B(x) \).

Where \( \mu_B(x) \) and \( \nu_B(x) \) represents the member and non-member ship function of X to B correspondingly. If B is a crisp set then either \( \mu_B(x) = 1, \nu_B(x) = 0 \ or \ \mu_B(x) = 0, \nu_B(x) = 1, \forall x \in X \).

If B is an IF set in X then
\[
\pi_B(x) = 1 - \mu_B(x) - \nu_B(x), 0 \leq \pi_B(x) + \nu_B(x) \leq 1, \forall x \in X
\]
(1)

where \( \pi_B(x) \) is hesitancy degree of X to B.

Statement 2 (De et al., 2000).
For each \( B \in X \), where \( B \) is IFS with respect to positive real number \( \sigma \) the IFS \( \sigma B \) is expressed as:
\[
\sigma B = \{ (x, 1 - (1 - \mu_B(x))^\sigma, (\nu_B(x))^\sigma) \} \in X
\]
(2)

2.2. Entropy of IFS

Shannon (1948) suggested entropy function in the year 1948, \( H(p_1, p_2, ..., p_n) = -\sum_{i=1}^{n} p_i \log(p_i) \) as a measure of uncertainty in discrete distribution on the basis of Boltzmann entropy in which probabilities \( p_i (i = 1, 2, ..., n) \) of random variable are calculated by probability mass function (P). Then De Luca and Termini (1972), created a formula of non-probabilistic entropy of a fuzzy set. Szmidt and Kacprzyk (2001) extended the entropy measure on IFSs (X). Vlachos et al. (2007) gave the measure of IF entropy as shown under:

\[
E_{IFS} = \frac{1}{n} \sum_{i=1}^{n} \left( \mu_B(x_i)^{1+\nu_B(x_i)} e^{-\frac{2}{\sigma} (\nu_B(x_i)+1-\mu_B(x_i))} \right) + \left( \nu_B(x_i)^{1+\mu_B(x_i)} e^{-\frac{2}{\sigma} (\mu_B(x_i)+1-\nu_B(x_i))} \right)
\]
(3)

Noted that \( E_{IFS} \) is comprised of hesitancy and fuzziness degree of IFS ‘B’.

1.3. Properties of entropy

Suppose X is the universal set and let P, Q \( \subseteq \) IFS (X) can be expressed by:
\[
P = \{ (t_x, \mu_P(t_x), \nu_P(t_x)) | t_x \in X \}
\]
and
\[
Q = \{ (t_x, \mu_Q(t_x), \nu_Q(t_x)) | t_x \in X \}
\]
(4)

Let E is an entropy, which is a real valued function such that IFS(X) \rightarrow [0,1] can satisfy these property (Szmidt and Kacprzyk, 2002):

(1) \( E(P) = 1 \) if \( \mu_P(x_i) = \nu_P(x_i) \) for \( \forall x \in X \).

(2) \( E(P) = 0 \) if P is crisp set, i.e. \( \mu_P(x_i) = 0, \nu_P(x_i) = 1 \) or \( \mu_P(x_i) = 1, \nu_P(x_i) = 0, \forall x_i \in X \).

(3) \( E(P) \leq E(Q) \) if \( P \subseteq Q \).

(4) \( E(P) = E(Q) \).
Where $\frac{1}{\ln n} \log_2 j = 1, 2, 3, 4, \ldots, n$ is a constant that ensures $0 \leq E^{IFS}_{ JS}(C_j) \leq 1$

In this way, degree of divergence is $d_j$ of average intrinsic data that has been given by the relating performance rating on criterion $C_j$ can be characterized as:

$$d_j = 1 - E^{IFS}_{ JS}(C_j), j = 1, 2, 3, \ldots, n$$

(13)

Now $j^{th}$ criterion’s entropy weight is given by:

$$w_j = \frac{d_j}{\sum_{j=1}^{n} d_j}$$

(14)

Step 3. Create the weighted IFDM.

A weighted IFDM ($\widetilde{R}$) can be attained by aggregating W and IFDM ($\widetilde{L}$) as described as:

$$\tilde{R} = \mathcal{W} \odot \tilde{L} = \mathcal{W} \odot [\tilde{x}_{ij}]_{m \times n} = [\tilde{x}_{ij}]_{m \times n} \text{ when } \mathcal{W} = (w_1, w_2, w_3, \ldots, w_p, \ldots, w_n)$$

$$\tilde{x}_{ij} = (\mu_{ij}, \upsilon_{ij}) = (1 - (\mu_{ij})^{w_i}v_{ij}^{w_j}, w_j > 0$$

(15)

Step 4. Determine IFPIS, $A^+$ (positive ideal) and IFNIS, $A^-$ (negative ideal), respectively.

Generally, evaluation of criteria may be classified into two parts, benefit and cost. Let G and B are collection of benefit & cost criteria, correspondingly. The IFPIS & IFNIS are expressed as:

$$A^+ = \left[ \begin{array}{c} \max \left\{ \mu_i \mid C_j \in G \right\} \\ \min \left\{ \upsilon_i \mid C_j \in B \right\} \\ \max \left\{ \mu_i \mid C_j \in G \right\} \\ \min \left\{ \upsilon_i \mid C_j \in B \right\} \end{array} \right]$$

($i = 1, 2, \ldots, m$)

$$A^- = \left[ \begin{array}{c} \max \left\{ \upsilon_i \mid C_j \in B \right\} \\ \min \left\{ \mu_i \mid C_j \in G \right\} \\ \min \left\{ \upsilon_i \mid C_j \in B \right\} \\ \max \left\{ \mu_i \mid C_j \in G \right\} \end{array} \right]$$

(16)

Step 5. The distance measures of each alternative $A_i$ from IFPIS and IFNIS.

By using (refer to Szmidt and Kacprzyk, 2001; 2002)

$$d_{IFS}(A_i, A^+) = \sqrt{\sum_{j=1}^{m} [\mu_{ij} - \mu_{ij}(C_j)]^2 + [\upsilon_{ij} - \upsilon_{ij}(C_j)]^2 + [\upsilon_{ij} - \mu_{ij}(C_j)]^2 + [\mu_{ij} - \upsilon_{ij}(C_j)]^2}$$

(17)

$$d_{IFS}(A_i, A^-) = \sqrt{\sum_{j=1}^{m} [\mu_{ij} - \upsilon_{ij}(C_j)]^2 + [\upsilon_{ij} - \mu_{ij}(C_j)]^2 + [\upsilon_{ij} - \mu_{ij}(C_j)]^2 + [\mu_{ij} - \upsilon_{ij}(C_j)]^2}$$

(18)

Step 6. Determine $CC_i$ and rank the all alternatives’ preference order.

The $CC_i$ of each alternative regarding IF ideal solution may be computed by:

$$CC_i = d_{IFS}(A_i, A^+)/[d_{IFS}(A_i, A^+) + d_{IFS}(A_i, A^-)], \quad 0 \leq CC_i \leq 1, i = 1, 2, \ldots, m$$

(19)

The most favoured alternative is one with the highest value of $CC_i$.

IV. CASE STUDY: DIAGNOSIS OF DIFFERENT TYPE OF DISEASE

Let there is a patient ($\alpha^1$) in a hospital at Delhi who is suffering from different type of fever due to mosquito’s bite. Doctors need to diagnosis the disease. Let us consider disease $\xi^C$ (Chikungunya), $\xi^D$ (Dengue), $\xi^M$ (Malaria) as alternatives with seven criteria, which include $S_1$ (Fever), $S_2$ (Joint Pain), $S_3$ (Chills and Rigors), $S_4$ Body Rash, $S_5$ (Retroorbital Head Ache), $S_6$ (Muscle Pain/ Body Pain), $S_7$ (vomiting/nausea) for further assignment. For evaluation of appropriate disease, three doctors such as $\omega^1$, $\omega^2$ and $\omega^3$ are approached for getting their opinion.

The committee of medical experts has given their opinion in the form of linguistic term as listed in Table I(c). Criteria weights for all three disease are presented in Table I(b) and weightage according to the symptoms of particular patient diagnosed by doctors as shown in Table I(c). In selection 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.

Step 1. The decision matrix (individual opinion of medical experts)

Now construct an IFDM (collective opinion of experts) using SIFWA operator

Step 2. Determine the CWs Using Eq. (12), the entropy values for criteria $S_1$, $S_2$, $S_3$, $S_4$, $S_5$, $S_6$, $S_7$ correspondingly are:

$$E_1 (S_1) = .6993, E_2 (S_2) = .6366, E_3 (S_3) = .7554, E_4 (S_4) = .6756, E_5 (S_5) = .6390, E_6 (S_6) = .6285, E_7 (S_7) = .6803.$$  The degree of divergence $d_j = 1 - E^{IFS}_{ JS}(C_j)$.

Step 3. Obtain ‘R’ by Eq. (15), the weighted IFDM

Step 4. In present case, criteria $S_1$, $S_2$, $S_3$, $S_4$, $S_5$, $S_6$, $S_7$ fit to benefit and $S_7$ fit to cost criterion. Using Eq.(16), each alternative’s IFPIS ($\xi^+$) and IFNIS ($\xi^-$) regarding criteria can be computed as:

$$\xi^+ = (0.9742, 0.7285), (0.9763, 0.6551), (0.9066, 0.9181), (0.9852, 0.6536), (0.9342, 0.8131), (0.9644, 0.6878), (0.7140, 0.9775)$$

$$\xi^- = (0.9730, 0.9662), (0.7544, 0.9593), (0.7728, 0.9828), (0.7105, 0.8929), (0.6230, 0.9835), (0.6145, 0.9830), (0.9693, 0.7246)$$

Step 5. The distance with alternatives and IF ideal solutions (IFPIS and IFNIS) using Eq. (17)

Step 6. The greater $CC_i$ specifies that an alternative is nearer to IFPIS and beyond from IFNIS concurrently. Thus, ranking order of all alternatives can be calculated according to the descending order of $CC_i$ and most favoured alternative is one with the highest value of $CC_i$. Using Eq. (18) the $CC_i$ can be obtained.
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Table 1(a). Verbal (Linguistic) terms for alternative’s and criteria’s rating

| 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) |

Table 1(b) Symptom’s weight by three experts for each disease

| Symptoms          | Dengue | Chikungunya | Malaria |
|-------------------|--------|--------------|---------|
| S₁                | VS     | VS           | VS      |
| S₂                | S      | S            | VS      |
| S₃                | P      | P            | P       |
| S₄                | S      | S            | S       |
| S₅                | VS     | VS           | P       |
| S₆                | S      | S            | P       |
| S₇                | P      | P            | P       |

Table 1(c). The individual opinion in the decision matrix form on three disease

| Symptoms | Doctors | Diseases |
|----------|---------|----------|
| S₁       | δ¹      | VG       |
|          | δ²      | F        |
|          | δ³      | P        |
| S₂       | δ¹      | VG       |
|          | δ²      | S        |
|          | δ³      | S        |
| S₃       | δ¹      | S        |
|          | δ²      | F        |
|          | δ³      | S        |
| S₄       | δ¹      | S        |
|          | δ²      | F        |
|          | δ³      | S        |
| S₅       | δ¹      | VS       |
|          | δ²      | F        |
|          | δ³      | S        |
| S₆       | δ¹      | VS       |
|          | δ²      | F        |
|          | δ³      | S        |
| S₇       | δ¹      | F        |
|          | δ²      | S        |
|          | δ³      | P        |

Table 2. The DOD and CWs

|          |          |          |          |
|----------|----------|----------|----------|
| d₁       | .3007    | d₂       | .3634    |
| W₁       | .1316    | W₂       | .1590    |

Table 3. Weighted IFDM (R)

| Alternatives | d₁ref(ξ⁺, ξ⁻) | d₁ref(ξ⁺, ξ⁻) | CCᵢ | Rank |
|--------------|----------------|----------------|------|------|
| ξ⁺           | 2.7062         | 2.8364         | 0.5718 | 1   |
| ξ⁻           | 2.6868         | 2.5871         | 0.4905 | 2   |
| ξᵢ           | 3.0708         | 2.7969         | 0.4767 | 3   |
Figure 2: Prediction of diseases using TOPSIS

Table 5. Ranking and disease diagnosis in the patients as below:

| Patients | Ranking of disease by TOPSIS | Disease diagnosed |
|----------|-----------------------------|------------------|
| α^4      | ξ^e > ξ^d > ξ^M             | Chikungunya      |
| α^2      | ξ^d > ξ^e > ξ^M             | Dengue           |
| α^1      | ξ^M > ξ^e > ξ^d             | Malaria          |
| α^4      | ξ^e > ξ^d > ξ^M             | Chikungunya      |

Table 6 (a). SWs of disease and aggregated IFDM

| Diseases | S_1  | S_2  | S_3  | S_4  | S_5  | S_6  | S_7  |
|----------|------|------|------|------|------|------|------|
| ξ^e      | .82  | .65  | .17  | .80  | .65  | .80  | .50  |
| ξ^d      | .86  | .73  | .77  | .86  | .73  | .73  | .50  |
| ξ^M      | .09  | .45  | .40  | .05  | .71  | .64  | .47  |
| ω_f      | .80  | .90  | .05  | .05  | .80  | .05  | .05  |

Table 6(b). Normalized SWs of criteria and NIFDs

| Diseases | S_1   | S_2   | S_3   | S_4   | S_5   | S_6   | S_7   |
|----------|-------|-------|-------|-------|-------|-------|-------|
| ξ^e      | 0.00  | 0.00  | 1.00  | 0.00  | 1.00  | 0.00  | 0.53  |
| ξ^d      | 0.26  | 0.94  | 0.68  | 0.30  | 0.79  | 0.03  | 0.55  |
| ξ^M      | 1.00  | 1.00  | 0.00  | 1.00  | 1.00  | 0.00  | 1.00  |
| ω_f      | 0.29  | 0.31  | 0.01  | 0.26  | 0.02  | 0.03  | 0.05  |

Table 6(c). OWs of diseases and evaluated IFE values

| Weights | S_1   | S_2   | S_3   | S_4   | S_5   | S_6   | S_7   |
|---------|-------|-------|-------|-------|-------|-------|-------|
| E_f     | .699  | .636  | .755  | .568  | .639  | .628  | .680  |
| ω_f     | .125  | .151  | .102  | .180  | .150  | .155  | .133  |

Table 7(a) S, R and Q values for three diseases

| Indexes | ξ^e  | ξ^d  | ξ^M  |
|---------|------|------|------|
| S       | .198 | .522 | .826 |
| R       | .087 | .219 | .232 |
| Q       | 0    | .712 | 1    |

Table 7(b) Ranking of three alternatives by S, R and Q

| Indexes | ξ^e  | ξ^d  | ξ^M  |
|---------|------|------|------|
| S       | 1    | 2    | 3    |
| R       | 1    | 2    | 3    |
| Q       | 1    | 2    | 3    |
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Table 7(c). Ranking and disease diagnosis in the patients as below:

| Patient | Ranking by VIKOR | Disease       |
|---------|------------------|---------------|
| α^1     | 1                 | Dengue        |
| α^2     | 2                 | Malaria       |
| α^3     | 3                 | Chikungunya   |
| α^4     | 4                 | Chikungunya   |

Validation of study
After evaluating the rank of disease by using TOPSIS, the by Opricovic, 1998 and Zhao et al. 2017 are used for validating the result. Thus, this technique can be recommended to give solution of disease selection and computational procedure has been discussed as under:

Step 1: We create consolidated IFDM by exploiting SIFWA operator by using 1(a) and 1(b). Relative outcomes have been revealed in Table 6(a).

Step 2: compute collective weightage of each criteria for relevant disease. Then, normalized SWs of criteria have been acquired as showed in Table 6(b).

Step 3: Each criterion’s IFE value has been attained based on the OW method and the criteria’s OWs have been computed which is presented in Table 6(c).

Step 4: Then S_1 to S_n are chosen as benefit criteria whereas S_i is considered as cost criterion. In this manner, we decide the IF positive and negative ideal solution of all the criteria ratings as observed below:

\[ \xi^+ = (0.17, 0.77), (0.09, 0.85), (0.05, 0.90), (0.80, 0.10) \]

\[ \xi^- = (0.82, 0.09), (0.40, 0.45), (0.90, 0.05), (0.65, 0.27), (0.80, 0.10), (0.09, 0.85) \]

Step 5: we can calculate the NIFDs as shown in Table 6(b).

Step 6: Now S, R and Q values are computed for 3 alternatives, which have been displayed in Table 7(a).

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

Step 8: On the basis of Table 7(b) the ranking of the three alternatives is in accordance with the Q value. The lowest Q value will be the most favored alternative while the highest value of Q will be the least favored alternative, or the alternatives can be calculated according to the ascending order of Q. Consequently, \( \xi^+ \) i.e., Chikungunya is the most likely disease among the other diseases. Table 7(a) shows S, R, and Q values for three diseases. The three alternatives are ranked as a \( \xi^+ > \xi^D > \xi^M \) and finally patient α^1 has been diagnosed with chikungunya. This proves the confirmation of our suggested technique. As per Table 7(b), 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 7(c). From Table 7c it is found by VIKOR method that patients α^2 and α^4 are suffering from chikungunya, whereas, α^2 and α^3 are facing dengue and malaria, respectively.

V. RESULT AND ANALYSIS

By using TOPSIS, the disease like chikungunya has occupied rank 1 among all the diseases and other patients were diagnosed with Dengue, Malaria and Chikungunya respectively. These results are also validated by using fuzzy VIKOR method, where same rank is obtained by the patients with the application of TOPSIS. Therefore, it is validated that the diseases can be better diagnosed with TOPSIS.

VI. CONCLUSION

The distance \( CC_j \) of three diseases are useful in providing order of rating among the alternatives. The only difference with respect to classical TOPSIS is that it is associates with objective entropy weight under IF environment. It provides relief to the doctors and also provides benefits to patients in a way that more precise and quickest diagnosis of concerned disease could be possible whereas, the current study has been applied only to four patients. Further, this method can be applied to large database of patients suffering with several types of VBDs to facilitate early diagnosis and immediate treatment. As a large number of people every year get affected with VBD, it becomes necessary to diagnose correct disease in the initial stage itself. So that patients shall get proper and timely treatments, and thus their life and resources may be saved from these types of diseases.

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