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# A VIKOR METHOD BASED ON BIPOLAR INTUITIONISTIC FUZZY SOFT SET

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ABSTRACT. This paper deals with classical VIKOR method using bipolar intuitionistic fuzzy soft Set $(BIFSS)$. The term VIKOR stands for "multi criteria optimization and compromise solution". First, the score function on $BIFSS$ is proposed to compute the score of each alternative and construct the score matrix of the collective bipolar intuitionistic fuzzy soft decision matrix. Bipolar intuitionistic fuzzy soft positive ideal and negative ideal solutions are found. $BIFS$ entropy is employed to compute the weight function. A method is framed for the multi criteria decision making. The values of group utility and individual regret value is determined and by this the compromising ranking solution is obtained. Having ranked the alternatives the best among them is chosen. Finally, an illustration is given to show the effectiveness and advantages of this method.

## 1. INTRODUCTION

Zadeh [8] introduced fuzzy sets and Atanassov [1] introduced the concept of intuitionistic fuzzy sets. Chiranjibe [3] developed the concept of bipolar intuitionistic fuzzy soft set.

Opricovic and Tzeng [4] introduced VIKOR method and developed a compromise solution by MCDM methods. Ali Shemshadi et.al., [6], have proposed

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VIKOR method based on fuzzy concept. [7] developed a group decision making with intuitionistic trapezoidal bipolar fuzzy information. Satyajit Das et.al., [5] have proposed a weight computation of criteria in decision making problem.

This paper deals with MCDM using VIKOR method based on $BIFS$ information and an example is given to show the working of this method.

## 2. $BIFS$ SCORE FUNCTION AND $BIFS$ ENTROPY MEASURE

Definition of $BIFS$ set is given in [2]. In this section, a score function of $BIFSS$ and a theorem based on score function is given. Then, a $BIFS$ entropy measure is defined.

**Definition 2.1.** $(BF, E) = \{((\mu^n_{BF(e)}, \mu^p_{BF(e)}), (\nu^n_{BF(e)}, \nu^p_{BF(e)}))\}$ *is a* $BIFSS$. *The hesitant degree of* $BIFSS$ *are* $\pi^n_{BF(e)}, \pi^p_{BF(e)}$ *respectively,*

$$\pi^n_{BF(e)} = -1 - \mu^n_{BF(e)} - \nu^n_{BF(e)} \quad \text{and} \quad \pi^p_{BF(e)} = 1 - \mu^p_{BF(e)} - \nu^p_{BF(e)},$$

*where* $\pi^n_{BF(e)} \in [-1, 0]$ *and* $\pi^p_{BF(e)} \in [0, 1]$.

**Definition 2.2.** *Let* $(BF, E)$ *and* $(BG, E)$ *be two* $BIFSS$. *Then,* $(BF, E) \subseteq (BG, E)$ *if*

$$\begin{aligned} \mu^n_{BF(e)}(x) \geq \mu^n_{BG(e)}(x), \quad \nu^n_{BF(e)}(x) \leq \nu^n_{BG(e)}(x), \\ \mu^p_{BF(e)}(x) \leq \mu^p_{BG(e)}(x), \quad \nu^p_{BF(e)}(x) \geq \nu^p_{BG(e)}(x), \end{aligned}$$

*respectively.*

**Definition 2.3.** *Each* $BIFS$ *set is taken as an alternative corresponding to each criteria and is represented as a* $s \times t$ $BIFS$ *matrix* $BIFSM$ *and defined as*

$$BIFSM = \begin{array}{c} \\ (BF_1,E) \\ (BF_2,E) \\ \\ (BF_s,E) \end{array} \begin{array}{c} \begin{array}{cccc} e_1 & e_2 & & e_t \end{array} \\ \begin{pmatrix} ((\mu^n_{11}, \mu^p_{11}), (\nu^n_{11}, \nu^p_{11})) & ((\mu^n_{12}, \mu^p_{12}), (\nu^n_{12}, \nu^p_{12})) & \cdots & ((\mu^n_{1t}, \mu^p_{1t}), (\nu^n_{1t}, \nu^p_{1t})) \\ ((\mu^n_{21}, \mu^p_{21}), (\nu^n_{21}, \nu^p_{21})) & ((\mu^n_{22}, \mu^p_{22}), (\nu^n_{22}, \nu^p_{22})) & \cdots & ((\mu^n_{2t}, \mu^p_{2t}), (\nu^n_{2t}, \nu^p_{2t})) \\ \cdots & \cdots & \cdots & \cdots \\ ((\mu^n_{s1}, \mu^p_{s1}), (\nu^n_{s1}, \nu^p_{s1})) & ((\mu^n_{s2}, \mu^p_{s2}), (\nu^n_{s2}, \nu^p_{s2})) & \cdots & ((\mu^n_{st}, \mu^p_{st}), (\nu^n_{st}, \nu^p_{st})) \end{pmatrix} \end{array}.$$

**Definition 2.4.** *Let* $(BF, E) = \{((\mu^n_{ij}, \mu^p_{ij}), (\nu^n_{ij}, \nu^p_{ij}))\}$ *be a* $BIFSS$. *The score function* $S_c(M)$ *of* $BIFSS(BF, E)$ *is defined as follows,* $S_c(M) = (M_{ij})_{s \times t}$, *where* $M_{ij} = (\mu^n_{ij} - \nu^n_{ij}) - (\mu^p_{ij} - \nu^p_{ij})) - (\pi^n_{ij} + \pi^p_{ij}) \times \dfrac{1 + \pi^n_{ij} + \pi^p_{ij}}{4}$, *where* $M_{ij} \in [-1, 1]$, $i = 1, 2, ..., s$, $j = 1, 2, ..., t$.

**Theorem 2.1.** *Let* $(BF,E) = ((\mu^n_{BF(e)}(x), \mu^p_{BF(e)}(x)), (\nu^n_{BF(e)}(x), \nu^p_{BF(e)}(x)))$ *and* $(BG,E) = ((\mu^n_{BG(e)}(x), \mu^p_{BG(e)}(x)), (\nu^n_{BG(e)}(x), \nu^p_{BG(e)}(x)))$ *be two* $BIFSS$*. If* $(BF,E) \neq (BG,E)$*, then* $S_c(BF,E) \neq S_c(BG,E)$*.*

*Proof.* If the $BIFSS$ $(BF,E) \subseteq (BG,E)$ then by Definition $2.2$,

$$\mu^n_{BF(e)} \geq \mu^n_{BG(e)},\ \nu^n_{BF(e)} \leq, \nu^n_{BG(e)} \quad \text{and} \quad \mu^p_{BF(e)} \leq \mu^n_{BG(e)},\ \nu^p_{BF(e)} \geq \nu^p_{BG(e)}.$$

Now,

$$\begin{aligned}
&S_c(BF,E) - S_c(BG,E)\\
&\quad = \Bigg( (\mu^n_{BF(e)} - \nu^n_{BF(e)}) - (\mu^p_{BF(e)} - \nu^p_{BF(e)}) - ((-1 - \mu^n_{BF(e)} - \nu^n_{BF(e)})\\
&\qquad + (1 - \mu^p_{BF(e)} - \nu^p_{BF(e)})) \times \tfrac{(1+(-1-\mu^n_{BF(e)}-\nu^n_{BF(e)})+(1-\mu^p_{BF(e)}-\nu^p_{BF(e)}))}{4} \Bigg)\\
&\qquad - \Bigg( (\mu^n_{BG(e)} - \nu^n_{BG(e)}) - (\mu^p_{BG(e)} - \nu^p_{BG(e)}) - ((-1 - \mu^n_{BG(e)} - \nu^n_{BG(e)})\\
&\qquad + (1 - \mu^p_{BG(e)} - \nu^p_{BG(e)})) \times \tfrac{(1+(-1-\mu^n_{BG(e)}-\nu^n_{BG(e)})+(1-\mu^p_{BG(e)}-\nu^p_{BG(e)}))}{4} \Bigg)\\
&\quad = \Bigg( \mu^n_{BF(e)} - \nu^n_{BF(e)} - \mu^p_{BF(e)} + \nu^p_{BF(e)} - ((-1 - \mu^n_{BF(e)} - \nu^n_{BF(e)})\\
&\qquad + (1 - \mu^p_{BF(e)} - \nu^p_{BF(e)})) \times \tfrac{(1+(-1-\mu^n_{BF(e)}-\nu^n_{BF(e)})+(1-\mu^p_{BF(e)}-\nu^p_{BF(e)}))}{4}\\
&\qquad - \mu^n_{BG(e)} + \nu^n_{BG(e)} + \mu^p_{BG(e)} - \nu^p_{BG(e)} + ((-1 - \mu^n_{BG(e)} - \nu^n_{BG(e)})\\
&\qquad + (1 - \mu^p_{BG(e)} - \nu^p_{BG(e)})) \times \tfrac{(1+(-1-\mu^n_{BG(e)}-\nu^n_{BG(e)})+(1-\mu^p_{BG(e)}-\nu^p_{BG(e)}))}{4} \Bigg)\\
&\Rightarrow (\mu^n_{BF(e)} - \mu^n_{BG(e)}) + (\nu^n_{BG(e)} - \nu^n_{BF(e)}) + (\mu^p_{BG(e)} - \mu^p_{BF(e)}) + (\nu^p_{BF(e)} - \nu^p_{BG(e)})\\
&\quad + \Bigg[ (-1 - \mu^n_{BG(e)} - \nu^n_{BG(e)}) + (1 - \mu^p_{BG(e)} - \nu^p_{BG(e)})\\
&\quad \times \tfrac{(1+(-1-\mu^n_{BG(e)}-\nu^n_{BG(e)})+(1-\mu^p_{BG(e)}-\nu^p_{BG(e)}))}{4}\\
&\quad - (-1 - \mu^n_{BF(e)} - \nu^n_{BF(e)})) + (1 - \mu^p_{BF(e)} - \nu^p_{BF(e)})\\
&\quad \times \tfrac{(1+(-1-\mu^n_{BF(e)}-\nu^n_{BF(e)})+(1-\mu^p_{BF(e)}-\nu^p_{BF(e)}))}{4} \Bigg],
\end{aligned}$$

since, $\mu^n_{BF(e)} \geq \mu^n_{BG(e)},\ \nu^n_{BF(e)} \leq \nu^n_{BG(e)}$ and $\mu^p_{BF(e)} \leq \mu^p_{BG(e)},\ \nu^p_{BF(e)} \geq \nu^p_{BG(e)}$.

Now, we have $(\mu^n_{BF(e)} - \mu^n_{BG(e)}) \geq 0$, $(\nu^n_{BG(e)} - \nu^n_{BF(e)}) \geq 0$, $(\mu^p_{BG(e)} - \mu^p_{BF(e)}) \geq 0$, $(\nu^p_{BF(e)} - \nu^p_{BG(e)}) \geq 0$, and

$$\Bigg[ (-1 - \mu^n_{BG(e)} - \nu^n_{BG(e)}) + (1 - \mu^p_{BG(e)} - \nu^p_{BG(e)}) \times \tfrac{(1+(-1-\mu^n_{BG(e)}-\nu^n_{BG(e)})+(1-\mu^p_{BG(e)}-\nu^p_{BG(e)}))}{4}$$

$$- ((-1 - \mu^n_{BF(e)} - \nu^n_{BF(e)}) + (1 - \mu^p_{BF(e)} - \nu^p_{BF(e)})) \times \frac{(1+(-1-\mu^n_{BF(e)}-\nu^n_{BF(e)})+(1-\mu^p_{BF(e)}-\nu^p_{BF(e)}))}{4}\Bigg] \neq 0.$$

Thus we have $S_c(BF, E) - S_c(BG, E) \neq 0$. Therefore, if $(BF, E) \subseteq (BG, E)$, then $S_c(BF, E) \neq S_c(BG, E)$.

Similarly, if $(BF, E) \supseteq (BG, E)$, then by Definition 2.2 we have $\mu^n_{BF(e)} \leq \mu^n_{BG(e)}$, $\nu^n_{BF(e)} \geq \nu^n_{BG(e)}$ and $\mu^p_{BF(e)} \geq \mu^p_{BG(e)}$, $\nu^p_{BF(e)} \leq \nu^p_{BG(e)}$, and further $(\mu^n_{BF(e)} - \mu^n_{BG(e)}) \leq 0$, $(\nu^n_{BG(e)} - \nu^n_{BF(e)}) \leq 0$, $(\mu^p_{BG(e)} - \mu^p_{BF(e)}) \leq 0$, $(\nu^p_{BF(e)} - \nu^p_{BG(e)}) \leq 0$, and

$$\Bigg[(-1 - \mu^n_{BG(e)} - \nu^n_{BG(e)}) + (1 - \mu^p_{BG(e)} - \nu^p_{BG(e)}) \times \frac{(1+(-1-\mu^n_{BG(e)}-\nu^n_{BG(e)})+(1-\mu^p_{BG(e)}-\nu^p_{BG(e)}))}{4} - (-1 - \mu^n_{BF(e)} - \nu^n_{BF(e)}) - (1 - \mu^p_{BF(e)} - \nu^p_{BF(e)}) \times \frac{(1+(-1-\mu^n_{BF(e)}-\nu^n_{BF(e)})+(1-\mu^p_{BF(e)}-\nu^p_{BF(e)}))}{4}\Bigg] \neq 0.$$

Therefore we have $S_c(BF, E) - S_c(BG, E) \neq 0$. Thus, if $(BF, E) \supseteq (BG, E)$, then $S_c(BF, E) \neq S_c(BG, E)$. Therefore, if $(BF, E) \neq (BG, E)$, then $S_c(BF, E) \neq S_c(BG, E)$. □

**Definition 2.5.** *For a $BIFSS$, the entropy measure is given by*

$$BE_j(BF_{e_j}(x)) = \frac{1}{4}\sum_{i=1}^{s}\left(\frac{1 - |\mu^n_{ij}(x) - \nu^n_{ij}(x)| - |\mu^p_{ij}(x) - \nu^p_{ij}(x)| + \pi^n_{ij}(x) + \pi^p_{ij}(x)}{1 + |\mu^n_{ij}(x) - \nu^n_{ij}(x)| + |\mu^p_{ij}(x) - \nu^p_{ij}(x)| + \pi^n_{ij}(x) + \pi^p_{ij}(x)}\right),$$

$j = 1, 2, ..., t.$

**Definition 2.6.** *The weight value of each criteria $w_j$ is $w_j = \dfrac{1 - BE_j}{\sum_{j=1}^{t}(1 - BE_j)}$. The weight vector $w_j = (w_1, w_2, ..., w_t)$ which satisfies $\sum_{j=1}^{t} w_j = 1$.*

2.1. **Problem statement.** Let $U = \{A_1, A_2, ..., A_s\}$ be a set of $s$ alternatives to be ranked with respect to the $t$ criteria $E = \{e_1, e_2, ..., e_t\}$. Each alternative $A_i$ is described by a $BIFSS$ over $U$. $A_i = \{((\mu^n_{i1}, \mu^p_{i1}), (\nu^n_{i1}, \nu^p_{i1})), ((\mu^n_{i2}, \mu^p_{i2}), (\nu^n_{i2}, \nu^p_{i2})), ..., ((\mu^n_{it}, \mu^p_{it}), (\nu^n_{it}, \nu^p_{it}))\}, i = 1, 2, ..., s$. Treating the data set as $BIFSS$ the best alternative is to be found using VIKOR method.

2.2. **VIKOR method based on** $BIFSS$**.** Now, VIKOR method is extended to $BIFSS$ and some of the concepts based on VIKOR method are defined.

**Definition 2.7.** *The $BIFS$ positive ideal solution $p_j^*$ and $BIFS$ negative ideal solution $p_j^-$ are defined as follows:*

$$p_j^* = \begin{cases} \max\limits_i M_{ij}, \text{ if } j \in f^1 \\ \min\limits_i M_{ij}, \text{ if } j \in f^2 \end{cases} \quad \text{and} \quad p_j^- = \begin{cases} \min\limits_i M_{ij}, \text{ if } j \in f^1 \\ \max\limits_i M_{ij}, \text{ if } j \in f^2 \end{cases},$$

*where $f^1$, $f^2$ denote the collection of benefit criteria and cost criteria respectively.*

**Definition 2.8.** *The $BIFS$ group utility value $BS_i$ of alternative $A_i$ is defined is defined by:*

$$BS_i = \sum_{j=1}^{t} w_j \frac{p_j^* - M_{ij}}{p_j^* - p_j^-}.$$

**Definition 2.9.** *The $BIFS$ individual regret value $BR_i$ of alternative $A_i$ is defined as follows:*

$$BR_i = \max_j \big(w_j \frac{p_j^* - M_{ij}}{p_j^* - p_j^-}\big).$$

**Definition 2.10.** *The value of $BQ_i$ is defined as follows:*

$$BQ_i = (Bw)\frac{BS_i - BS^*}{BS' - BS^*} + (1 - Bw)\frac{BR_i - BR^*}{BR' - BR^*},$$

*where $BS^* = \min\limits_i\{BS_i\}$, $BS^{'} = \max\limits_i\{BS_i\}$, $BR^* = \min\limits_i\{BR_i\}$, $BR^{'} = \max\limits_i\{BR_i\}$ where $Bw \in [0, 1]$, is the weight corresponding to the strategy of the maximum of group utility and(1-Bw)represents the weight of individual regret. Minimum value of $BQ_i$, indicates the better alternative.*

**Definition 2.11.** *To find the compromising solution: The following two cases must be satisfied to ensure the best alternative. The two cases are defined as follows:*

*Case 1: Acceptable advantage:*

$BQ_i(A^2) - BQ_i(A^1) \geq DQ$,

*where $DQ = \frac{1}{s-1}$ and $s$ denotes number of alternatives. $A^1$ is the alternative corresponding to the minimum value of $BQ_i$ and $A^2$ is the alternative corresponding to the next higher values of $BQ_i$.*

*Case 2: Acceptable stability:*

*The alternative $A^1$ is best ranked using $BS_i$ and $BR_i$.*

*If Case 1 is not satisfied, then the compromise solutions are alternatives* $A^1$ *and* $A^2$. *If Case 2 is not satisfied, then a relation* $BQ(A^t - A^1) < D_Q$ *is obtained and we get a compromising solution* $A^1, A^2, ..., A^s$.

2.3. **Procedure.** MCDM problem using VIKOR method is as follows:

**Step 1:** Construct the $BIFS$ decision matrix $BIFSM$ using Definition 2.3.

**Step 2:** Determine the score matrix $(M_{ij})_{s\times t}$ corresponding to the criteria $e_j$, by using Definition 2.4.

**Step 3:** Compute the $BIFS$ positive ideal solution $p_j^*$ and $BIFS$ negative ideal solution $p_j^-$ for each criteria $e_j$ using Definition 2.8.

**Step 4:** Calculate the $BIFS$ entropy measure $BE_j$ using Definition 2.6.

**Step 5:** Compute the $BIFS$ weight values $w_j$ by using Definitions 2.7.

**Step 6:** Determine the $BIFS$ group utility value $BS_i$, $BIFS$ individual regret value $BR_i$ and the values of $BQ_i$ by using Definitions 2.9, 2.10 and 2.11. According to the values of $BS_i$, $BR_i$ and $BQ_i$ rank the alternatives.

**Step 7:** Compute the compromising ranking list by satisfying the two cases using Definition 2.12.

**Example 1.** *A person wants to cultivate a best yielding wheat crop. Hence he decides to find out the best yielding variety. Different varieties of wheat crop are taken as the set of alternatives i.e.,* $U = \{CV_1, CV_2, CV_3, CV_4, CV_5\}$*, where each alternatives is a* $BIFSS$*. The person has to decide which variety of wheat crop is the best depending on the criteria* $E = \{e_1, e_2, e_3, e_4\}$ *where* $e_1$ = *climatic condition,* $e_2$ = *cost,* $e_3$ =*application of manures and fertilizers and* $e_4$ = *seed quality respectively.*

**Step 1:** $BIFS$ matrix is:

$$\begin{array}{c|cccc} & e_1 & e_2 & e_3 & e_4 \\ \hline CV_1 & ((-0.2,0.62),(-0.4,0.18)) & ((-0.14,0.45),(-0.3,0.11)) & ((-0.36,0.57),(-0.5,0.2)) & ((-0.1,0.28),(-0.15,0.07)) \\ CV_2 & ((-0.13,0.32),(-0.24,0.040.09)) & ((-0.3,0.56),(-0.4,0.2)) & ((-0.26,0.7),(-0.3,0.15)) & ((-0.19,0.5),(-0.22,0.13)) \\ CV_3 & ((-0.14,0.86),(-0.2,0.1)) & ((-0.12,0.6),(-0.58,0.07) & ((-0.2,0.6),(-0.5,0.1)) & ((-0.26,0.37),(-0.16,0.08)) \\ CV_4 & ((-0.47,0.5),(-0.38,0.26)) & ((-0.13,0.31),(-0.28,0.1)) & ((-0.11,0.42),(-0.23,0.08)) & ((-0.25,0.46),(-0.4,0.13)) \\ CV_5 & ((-0.35,0.57),(-0.45,0.2)) & ((-0.14,0.72),(-0.7,0.12)) & ((-0.3,0.82),(-0.53,0.12)) & ((-0.32,0.63),(-0.43,0.1)) \end{array}$$

**Step 2:** $BIFS$ score matrix $S_c(M)$ is as follows:

$$(M_{ij}) = \begin{pmatrix} 0.072 & 0.1804 & 0.038 & 0.2387 \\ 0.264 & 0.066 & 0.014 & 0.121 \\ 0.016 & 0.28 & 0.197 & 0.179 \\ 0.18 & 0.045 & 0.172 & 0.154 \\ 0.04 & 0.265 & 0.055 & 0.025 \end{pmatrix}$$

**Step 3:** $BIFS$ positive ideal solution $p_j*$ and $BIFS$ negative ideal solution $p_j-$ are:

| $U$ | $e_1$ | $e_2$ | $e_3$ | $e_4$ |
|---|---|---|---|---|
| $p_j^*$ | 0.264 | 0.045 | 0.197 | 0.239 |
| $p_j^-$ | 0.016 | 0.28 | 0.014 | 0.024 |

**Step 4:** $BIFS$ entropy value $BE_j$ is:
$BE_1 = 0.44$, $BE_2 = 0.282$, $BE_3 = 0.177$ and $BE_4 = 0.43$,

**Step 5:** The values of weight function $w_j$, based on the criteria $e_j$
$w_1 = 0.21$, $w_2 = 0.269$, $w_3 = 0.308$, and $w_4 = 0.213$.

**Step 6:** Compute the values of $BS_i$, $BR_i$ and $BQ_i$:

| $U$ | $BS_i$ | $BR_i$ | $BQ_i$ |
|---|---|---|---|
| $CV_1$ | 0.5855 | 0.267 | 0.758 |
| $CV_2$ | 0.4489 | 0.308 | 0.733 |
| $CV_3$ | 0.5384 | 0.269 | 0.722 |
| $CV_4$ | 0.1718 | 0.084 | 0 |
| $CV_5$ | 0.764 | 0.25 | 0.874 |

**Step 7:** Compute the compromising ranking: By sorting the values of $BS_i$, $BR_i$ and $BQ_i$, $CV_4$ has the minimum $BQ_i$ value. So it ranks first. The value $CV_3$ occupies the second position. Now, we verify the two conditions that is

$$BQ(A_3) - BQ(A_4) \geq \frac{1}{s-1}; 0.722 - 0 \geq \frac{1}{4-1}; 0.722 \geq 0.25.$$

Condition $c^1$ is satisfied. Next we verify condition $c^2$. i.e., The alternative $CV_4$ is ranked by all the other values of $BS_i$ and $BR_i$. Therefore, condition $c^2$ is satisfied. Therefore $CV_4$ is the best yielding wheat crop.

The values of $BS_i$, $BR_i$ and $BQ_i$ are represented graphically. We find that $CV_4$ has the minimum value. This reveals that the alternative $CV_4$ indicates the best yielding wheat crop.

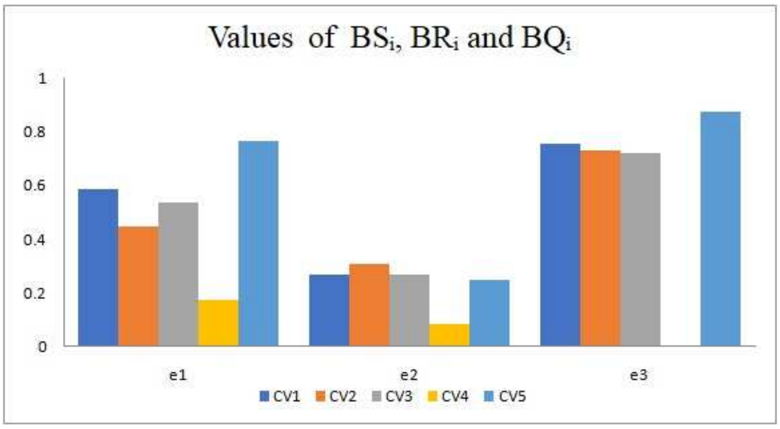


FIGURE 1

## 3. CONCLUSION

The score function proposed is effective. The $BIFS$ entropy measure is developed and it serves as a tool in computing the weight values for each criteria.

## REFERENCES


[1] K. ATANASSOV: *Intuitionistic fuzzy sets*, Fuzzy. Set. Syst., **20**(1) (1986), 87–96.

[2] S. A. SHANTHI, P. JAYAPALAN: *A multi-criteria decision making problem based on score function of bipolar intuitionistic fuzzy soft set*, AIP conference proceedings, **2177** (2019), 020004, 1–6.

[3] C. JANA, M. PAL: *Application of bipolar intuitionistic fuzzy soft sets in decision making problem*, Int. J. Fuzzy. Syst. Appl., **7**(3) (2018), 33–55.

[4] S. OPRICOVIC, T. ZENG: *Compromise solution by MCDM methods: comparative analysis of VIKOR and TOPSIS*, Eur. J. Oper. Res., **156** (2004), 445–455.

[5] S. DAS, B. DUTTA, D. GUHA: *Weight computation of criteria in a decision- making problem by knowledge measure with intuitionistic fuzzy set and interval-valued intuitionistic fuzzy set*, Soft Computing, **20**(2016), 3421–3442.

[6] A. SHEMSHADI, H. SHIRAZI, M. TOREIHI, M. J. TAROKH: *A fuzzy VIKOR method for supplier selection based on entropy measure for objective weighting*, Expert. Syst. Appl., **38**(2011), 12160–12167.

[7] SHUMAIZA, M. AKRAM, A. N. KENANI, J. C. R. ALCANTUD: *Group decision-making based on the VIKOR method with trapezoidal bipolar fuzzy information*, Symmetry, **11**(1313) (2019), 1–21.

[8] L.A. ZADEH: *Fuzzy sets*, Inf. Cont., **8** (1965), 338–353.

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