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Models for Single-valued Neutrosophic Multiple Attribute Decision Making and its Application to Credit Risk Evaluation of Small New Venture' Indirect Financing

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Abstract

The dual generalized WBM (DGWBM) operator is a very practical tool to tackle the arguments which are correlated. The Single-valued neutrosophic sets (SVNSs) are effective is to depict the uncertainty and ambiguity in real multiple attribute decision making. The credit risk evaluation of small new venture' indirect financing is always regarded as multiple attribute decision making problem. In this article, we utilized the dual generalized Single-valued neutrosophic number weighted Bonferroni mean (DGSVNNWBM) operator to solve the MADM problem. In the end, we utilize an applicable example for credit risk evaluation of small new venture' indirect financing to prove the proposed methods.

Keywords

Multiple Attribute Decision Making; Single-valued Neutrosophic Numbers; Dual Generalized Single-valued Neutrosophic Number WBM (DGSVNNWBM) Operator; Credit Risk Evaluation.

1. Introduction

Since the process of making decision is filled with uncertainty and ambiguity[1-4], thus, in order to cope with the accuracy of decision-making, Zadeh [5] proposed the fuzzy sets (FSs). Atanassov [6] proposed the intuitionistic fuzzy sets (IFSs). Rouyendegh [7]used the ELECTRE method in IFSs to tackle some MCDM issues. Chen, Cheng and Lan [8] developed TOPSIS method and similarity measures under IFSs. Gan and Luo [9]used the hybrid method with DEMATEL and IFSs. He, He and Huang [10]integrated the power averaging with IFSs. Hao, Xu, Zhao and Zhang [11]presented a theory of decision field for IFSs. Jin, Ni, Chen and Li [12]defined two GDM methods which can obtain the normalized intuitionistic fuzzy priority weights from IFPRs on the basis of the order consistency and the multiplicative consistency. Krishankumar, Arvinda, Amrutha, Premaladha, Ravichandran and Ieee [13]integrated AHP with IFSs to design a GDM method for effective cloud vendor selection. Bao, Xie, Long and Wei [14]defined prospect theory and evidential reasoning method under IFSs. Gupta, Mehlawat, Grover and Chen [15]modified the SIR method and combined it with IFSs. Garg [16]presented a method related to MAGDM on the basis of intuitionistic fuzzy multiplicative preference and defined several geometric operators. Gupta, Arora and Tiwari [17]extended the fuzzy entropy to IFSs. Xiao, Zhang, Wei, Wu, Wei, Guo and Wei [18] defined the intuitionistic fuzzy Taxonomy method. Li and Wu [19]presented the intuitionistic fuzzy cross entropy distance. Cali and Balaman [20]extended ELECTRE I with VIKOR method in IFSs to reflect the decision makers' preferences. Gou, Xu and Lei [21] defined some exponential operational law for IFNs. Khan, Lohani and Ieee [22]defined similarity measure about IFNs. Li, Liu, Liu, Su and Wu [23]gave a grey target decision making with IFNs. Liu, Liu and Chen [24] built some intuitionistic fuzzy BM fused operators with Dombi operations. Zhang, Ju and Liu [25] defined the programming technique for MAGDM based on Shapley values and incomplete information.

Wang, Smarandache, Zhang and Sunderraman [26] built the neutrosophic set theory. Wang, Smarandache, Zhang and Sunderraman [27] defined the concepts of a Single-valued neutrosophic set (SVNS). Ye [28] defiined the vector similarity measures of simplified neutrosophic sets in multicriteria decision making. Liu and Wang [29] defined the Single-valued neutrosophic normalized weighted Bonferroni mean operators. Ye [30] defined the single valued neutrosophic cross-entropy for multicriteria decision making problems. Zavadskas, Bausys and Lazauskas [31] built the Sustainable assessment of alternative sites for the construction of a waste incineration plant by applying WASPAS method with Single-valued neutrosophic set. Ye [32] improved cross entropy measures of single valued neutrosophic sets. Biswas, Pramanik and Giri [33] built the TOPSIS method for MAGDM under Single-valued neutrosophic environment. Liu [34] built the aggregation operators based on archimedean t-conorm and t-norm for Single-valued neutrosophic numbers for decision making. Chen and Ye [35] defined some Single-valued neutrosophic dombi weighted aggregation operators for multiple attribute decision-making. Zavadskas, Bausys, Juodagalviene and Garnyte-Sapranaviciene [36] defined the model for residential house element and material selection by neutrosophic MULTIMOORA method.

In this article, we utilized the dual generalized Single-valued neutrosophic number WBM (DGSVNNWBM) operator. The structure of this manuscript is given. Section 2 reviews SVNSs and basic definitions. Section 3 introduces the extended DGWBM which can be used to fuse the SVNNs, and describes some properties of these operators. Section 4 illustrates the functions of the proposed operators with an example for credit risk evaluation of small new venture' indirect financing. Section 5 concludes.

2. Basic Concepts

Wang, Smarandache, Zhang and Sunderraman [27] defined the Single-valued neutrosophic set.

Definition 1[27]. Let X be a space of points (objects) with a generic element in fix set X, denoted by x. A Single-valued neutrosophic sets (SVNSs) A in X is characterized as following:

$$A=\left\{\left(x,T_A(x),I_A(x),F_A(x)\right)\middle|x\in X\right\} \tag{1}$$

where the truth-membership function $T_A(x)$, indeterminacy-membership $I_A(x)$ and falsity-membership function $F_A(x)$ are single subintervals/subsets in the real standard $[0,1]$, that is, $T_A(x):X\to[0,1]$, $I_A(x):X\to[0,1]$ and $F_A(x):X\to[0,1]$. And the sum of $T_A(x)$, $I_A(x)$ and $F_A(x)$ satisfies the condition $0\le T_A(x)+I_A(x)+F_A(x)\le 3$. Then a simplification of A is denoted by $A=\left\{\left(x,T_A(x),I_A(x),F_A(x)\right)\middle|x\in X\right\}$, which is a SVNS. a Single-valued neutrosophic number (SVNN) is denoted by $\tilde{a}=(\mu,\rho,\nu)$ for convenience.

Definition 2[37]. Let $\tilde{a}=(\mu,\rho,\nu)$ be a SVNN, a score function S of a SVNN is represented:

$$S(\tilde{a})=\frac{1+\mu-2\rho-\nu}{2},\ S(\tilde{a})\in[-1,1]. \tag{2}$$

Definition 3[37]. Let $\tilde{a}=(\mu,\rho,\nu)$ be a SVNN, an accuracy function H of a SVNN is:

$$H(\tilde{a})=\frac{1+\mu-\rho(1-\mu)-\nu(1-\rho)}{2},\ H(\tilde{a})\in[0,1]. \tag{3}$$

to evaluate the degree of accuracy of the Single-valued neutrosophic number $\tilde{a}=(\mu,\rho,\nu)$, where $H(\tilde{a})\in[0,1]$. The larger the value of $H(\tilde{a})$, the more the degree of accuracy of the Single-valued neutrosophic number $\tilde{a}$.

Then, Sahin and Liu [37] gave an order relation between two SVNNs.

Definition 4[37]. Let $\tilde{a}_1=(\mu_1,\rho_1,\nu_1)$ and $\tilde{a}_2=(\mu_2,\rho_2,\nu_2)$ be two SVNNs, $S(\tilde{a}_1)=\frac{1+\mu_1-2\rho_1-\nu_1}{2}$ and $S(\tilde{a}_2)=\frac{1+\mu_2-2\rho_2-\nu_2}{2}$ be the scores of $\tilde{a}_1$ and $\tilde{a}_2$, respectively, and let $H(\tilde{a}_1)=\frac{1+\mu_1-\rho_1(1-\mu_1)-\nu_1(1-\rho_1)}{2}$ and $H(\tilde{a}_2)=\frac{1+\mu_2-\rho_2(1-\mu_2)-\nu_2(1-\rho_2)}{2}$ be the accuracy degrees of $\tilde{a}_1$ and $\tilde{a}_2$, respectively, then if $S(\tilde{a}_1)<S(\tilde{a}_2)$, then $\tilde{a}_1$ is smaller than $\tilde{a}_2$, denoted by $\tilde{a}_1<\tilde{a}_2$; if $S(\tilde{a}_1)=S(\tilde{a}_2)$, then (1) if $H(\tilde{a}_1)=H(\tilde{a}_2)$, then $\tilde{a}_1$ and $\tilde{a}_2$ represent the same information, denoted by $\tilde{a}_1=\tilde{a}_2$; (2) if $H(\tilde{a}_1)<H(\tilde{a}_2)$, $\tilde{a}$ is smaller than $\tilde{b}$, denoted by $\tilde{a}_1<\tilde{a}_2$.

Zhang, Wang, Zhu, Xia and Yu [38] developed the dual generalized WBM (DGWBM) operator.

Definition 4[38]. Let $b_i(i=1,2,\ldots,n)$ be a set of nonnegative crisp numbers with the weight $w=(w_1,w_2,\ldots,w_n)^T$, $w_i\in[0,1]$ $(i=1,2,\ldots,n)$ and $\sum_{i=1}^{n}w_i=1$. If

$$\mathrm{DGWBM}_w^R(b_1,b_2,\ldots,b_n)=\left(\sum_{i_1,i_2,\ldots,i_n=1}^{n}\left(\prod_{j=1}^{n}w_{i_j}b_{i_j}^{r_j}\right)\right)^{1/\sum_{j=1}^{n}r_j} \tag{4}$$

where $R=(r_1,r_2,\ldots,r_n)^T$ is the parameter vector with $r_i\geq 0(i=1,2,\ldots,n)$.

Several special cases can be obtained given the change of the parameter vector.

If $R=(\lambda,0,0,\ldots,0)$, then we obtain

$$\mathrm{DGWBM}^{(\lambda,0,0,\ldots,0)}(b_1,b_2,\ldots,b_n)=(\sum_{i=1}^{n}w_ib_i^{\lambda})^{1/\lambda} \tag{5}$$

which is the generalized weighted averaging operator.

If $R=(s,t,0,0,\ldots,0)$, then we obtain

$$\mathrm{DGWBM}^{(s,t,0,0,\ldots,0)}(b_1,b_2,\ldots,b_n)=(\sum_{i,j=1}^{n}w_iw_jb_i^sb_j^t)^{1/(s+t)} \tag{6}$$

which is the weighted BM.

If $R=(s,t,r,0,0,\ldots,0)$, then we obtain

$$\mathrm{DGWBM}^{(s,t,r,0,0,\ldots,0)}(b_1,b_2,\ldots,b_n)=(\sum_{i,j,k=1}^{n}w_iw_jw_kb_i^sb_j^tb_k^r)^{1/(s+t+k)} \tag{7}$$

3. DGSVNNWBM Operator

Wang, Tang and Wei [39] extended DGWBM to fuse the SVNNs and proposed the dual generalized SVNN weighted BM (DGSVNNWBM) operator.

Definition 5 [39]. Let $a_i=(T_i,I_i,F_i)(i=1,2,\ldots,n)$ be a set of SVNNs with weight $w_i=(w_1,w_2,\ldots,w_n)^T$, $w_i\in[0,1]$ and $\sum_{i=1}^{n}w_i=1$.

Thereafter the Dual Generalized SVNN weighted BM (DGSVNNWBM) operator is defined as

$$\mathrm{DGSVNNWBM}_w^R(a_1,a_2,\cdots,a_n)=\left(\bigoplus_{i_1,i_2,\ldots,i_n=1}^{n}\left(\bigotimes_{j=1}^{n}w_{i_j}a_{i_j}^{r_j}\right)\right)^{1/\sum_{i=1}^{n}r_j} \tag{8}$$

where $R=(r_1,r_2,\ldots,r_n)^T$ is the parameter vector with $r_i\geq 0(i=1,2,\ldots,n)$.

Theorem 1[39]. Let $a_i=(T_i,I_i,F_i)(i=1,2,\ldots,n)$ be a set of SVNNs. Hence, the aggregated result of DGSVNNWBM is a SVNN and

$$\begin{aligned}&\mathrm{DGSVNNWBM}_w^R(a_1,a_2,\cdots,a_n)\\&=\left(\begin{array}{l}\left(1-\prod_{i_1,i_2,\ldots i_n=1}^{n}\left(1-\prod_{j=1}^{n}\left(1-\left(1-T_{i_j}^{r_j}\right)^{w_{i_j}}\right)\right)\right)^{1/\sum_{i=1}^{n}r_j},\\ 1-\left(1-\prod_{i_1,i_2,\ldots,i_n=1}^{n}\left(1-\prod_{j=1}^{n}\left(1-\left(1-\left(1-I_{i_j}\right)^{r_j}\right)^{w_{i_j}}\right)\right)\right)^{1/\sum_{i=1}^{n}r_j},\\ 1-\left(1-\prod_{i_1,i_2,\ldots,i_n=1}^{n}\left(1-\prod_{j=1}^{n}\left(1-\left(1-\left(1-F_{i_j}\right)^{r_j}\right)^{w_{i_j}}\right)\right)\right)^{1/\sum_{i=1}^{n}r_j}.\end{array}\right)\end{aligned} \tag{9}$$

Proof:

$$a_{i_j}^{r_j}=\left(T_{i_j}^{r_j},1-\left(1-I_{i_j}\right)^{r_j},1-\left(1-F_{i_j}\right)^{r_j}\right). \tag{10}$$

Thus,

$$w_{i_j}a_{i_j}^{r_j}=\left(1-\left(1-T_{i_j}^{r_j}\right)^{w_{i_j}},\left(1-\left(1-I_{i_j}\right)^{r_j}\right)^{w_{i_j}},\left(1-\left(1-F_{i_j}\right)^{r_j}\right)^{w_{i_j}}\right). \tag{11}$$

Thereafter,

$$\bigotimes_{j=1}^{n}w_{i_j}a_{i_j}^{r_j}=\left(\begin{array}{l}\prod_{j=1}^{n}\left(1-\left(1-T_{i_j}^{r_j}\right)^{w_{i_j}}\right),\\ 1-\prod_{j=1}^{n}\left(1-\left(1-\left(1-I_{i_j}\right)^{r_j}\right)^{w_{i_j}}\right),\\ 1-\prod_{j=1}^{n}\left(1-\left(1-\left(1-F_{i_j}\right)^{r_j}\right)^{w_{i_j}}\right)\end{array}\right) \tag{12}$$

Furthermore,

$$\underset{i_1,i_2,\ldots,i_n=1}{\overset{n}{\oplus}}\left(\overset{n}{\underset{j=1}{\otimes}} w_{i_j} a_{i_j}^{r_j}\right)$$
$$=\begin{pmatrix} 1-\prod_{i_1,i_2,\ldots,i_n=1}^{n}\left(1-\prod_{j=1}^{n}\left(1-\left(1-T_{i_j}^{r_j}\right)^{w_{i_j}}\right)\right), \\ \prod_{i_1,i_2,\ldots,i_n=1}^{n}\left(1-\prod_{j=1}^{n}\left(1-\left(1-\left(1-I_{i_j}\right)^{r_j}\right)^{w_{i_j}}\right)\right), \\ \prod_{i_1,i_2,\ldots,i_n=1}^{n}\left(1-\prod_{j=1}^{n}\left(1-\left(1-\left(1-F_{i_j}\right)^{r_j}\right)^{w_{i_j}}\right)\right). \end{pmatrix} \tag{13}$$

Therefore,

$$\left(\underset{i_1,i_2,\ldots,i_n=1}{\overset{n}{\bigoplus}}\left(\overset{n}{\underset{j=1}{\bigotimes}} w_{i_j} a_{i_j}^{r_j}\right)\right)^{1/\sum_{i=1}^{n} r_j}$$
$$=\begin{pmatrix} \left(1-\prod_{i_1,i_2,\ldots i_n=1}^{n}\left(1-\prod_{j=1}^{n}\left(1-\left(1-T_{i_j}^{r_j}\right)^{w_{i_j}}\right)\right)\right)^{1/\sum_{i=1}^{n} r_j}, \\ 1-\left(1-\prod_{i_1,i_2,\ldots,i_n=1}^{n}\left(1-\prod_{j=1}^{n}\left(1-\left(1-\left(1-I_{i_j}\right)^{r_j}\right)^{w_{i_j}}\right)\right)\right)^{1/\sum_{i=1}^{n} r_j}, \\ 1-\left(1-\prod_{i_1,i_2,\ldots,i_n=1}^{n}\left(1-\prod_{j=1}^{n}\left(1-\left(1-\left(1-F_{i_j}\right)^{r_j}\right)^{w_{i_j}}\right)\right)\right)^{1/\sum_{i=1}^{n} r_j}. \end{pmatrix} \tag{14}$$

Hence, (11) is maintained.
Thereafter,

$$\begin{aligned} 0 &\le \left(1-\prod_{i_1,i_2,\ldots i_n=1}^{n}\left(1-\prod_{j=1}^{n}\left(1-\left(1-T_{i_j}^{r_j}\right)^{w_{i_j}}\right)\right)\right)^{1/\sum_{i=1}^{n} r_j} \le 1, \\ 0 &\le 1-\left(1-\prod_{i_1,i_2,\ldots,i_n=1}^{n}\left(1-\prod_{j=1}^{n}\left(1-\left(1-\left(1-I_{i_j}\right)^{r_j}\right)^{w_{i_j}}\right)\right)\right)^{1/\sum_{i=1}^{n} r_j} \le 1, \\ 0 &\le 1-\left(1-\prod_{i_1,i_2,\ldots,i_n=1}^{n}\left(1-\prod_{j=1}^{n}\left(1-\left(1-\left(1-F_{i_j}\right)^{r_j}\right)^{w_{i_j}}\right)\right)\right)^{1/\sum_{i=1}^{n} r_j} \le 1. \end{aligned} \tag{15}$$

In addition,

$$\begin{aligned} 0 \le &\left(1-\prod_{i_1,i_2,\ldots i_n=1}^{n}\left(1-\prod_{j=1}^{n}\left(1-\left(1-T_{i_j}^{r_j}\right)^{w_{i_j}}\right)\right)\right)^{1/\sum_{i=1}^{n} r_j} \\ &+1-\left(1-\prod_{i_1,i_2,\ldots,i_n=1}^{n}\left(1-\prod_{j=1}^{n}\left(1-\left(1-\left(1-I_{i_j}\right)^{r_j}\right)^{w_{i_j}}\right)\right)\right)^{1/\sum_{i=1}^{n} r_j} \\ &+1-\left(1-\prod_{i_1,i_2,\ldots,i_n=1}^{n}\left(1-\prod_{j=1}^{n}\left(1-\left(1-\left(1-F_{i_j}\right)^{r_j}\right)^{w_{i_j}}\right)\right)\right)^{1/\sum_{i=1}^{n} r_j} \le 3. \end{aligned} \tag{16}$$

Thereby completing the proof.

Moreover, DGSVNNWBM has the following properties[39].

Property 1.(Monotonicity). Let $a_i = (T_{a_i}, I_{a_i}, F_{a_i})(i = 1,2,\ldots,n)$ and $b_i = (T_{b_i}, I_{b_i}, F_{b_i})$ $(i = 1,2,\ldots,n)$ be two sets of SVNNs. If $T_{a_i} \le T_{b_i}$ *and* $I_{a_i} \ge I_{b_i}$ *and* $F_{a_i} \ge F_{b_i}$ holds for all i, then

$$\mathrm{DGSVNNWBM}_w^R(a_1, a_2, \cdots, a_n) \le \mathrm{DGSVNNWBM}_w^R(b_1, b_2, \cdots, b_n). \tag{17}$$

Property 2. (Boundedness). Let $a_i = (T_{a_i}, I_{a_i}, F_{a_i})(i = 1,2,\ldots,n)$ be a set of SVNNS. If $a^+ = (\max_i(T_i), \min_i(I_i), \min_i(F_i))$ and $a^- = (\min_i(T_i), \max_i(I_i), \max_i(F_i))$, then

$$\begin{aligned} &\mathrm{DGSVNNWBM}_w^R(a_1^-, a_2^-, \cdots, a_n^-) \\ &\le \mathrm{DGSVNNWBM}_w^R(a_1, a_2, \cdots, a_n) \\ &\le \mathrm{DGSVNNWBM}_w^R(a_1^+, a_2^+, \cdots, a_n^+) \end{aligned} \tag{18}$$

4. Applicable Example and Influence Analysis

4.1. Applicable Example

In this section we give a numerical example for credit risk evaluation of small new venture' indirect financing with SVNNs in order to illustrate the method proposed in this paper. There is a panel with five possible enterprises $O_i\left(i = 1,2,3,4,5\right)$ to select. The experts select four attributes to evaluate the five possible enterprises: ①C1 is the corporate profitability; ②C2 is the solvency ability; ③C3 is the viability ability; ④C4 is the development capacity. The five possible enterprises $O_i\left(i = 1,2,3,4,5\right)$ are to be evaluated using the SVNNs by the decision maker under the above four attributes (whose weighting vector $\omega = \left(0.15, 0.40, 0.30, 0.15\right)^T$), as listed in the following matrix.

$$\tilde{R} = \begin{bmatrix} (0.7,0.8,0.3) & (0.7,0.5,0.6) & (0.4,0.7,0.2) & (0.8,0.5,0.2) \\ (0.6,0.8,0.3) & (0.7,0.8,0.4) & (0.7,0.6,0.6) & (0.9,0.6,0.2) \\ (0.8,0.6,0.4) & (0.6,0.8,0.4) & (0.5,0.8,0.2) & (0.7,0.4,0.3) \\ (0.6,0.7,0.3) & (0.6,0.5,0.3) & (0.4,0.4,0.6) & (0.9,0.2,0.4) \\ (0.6,0.8,0.4) & (0.6,0.7,0.8) & (0.6,0.6,0.7) & (0.6,0.9,0.4) \end{bmatrix}$$

Then, we utilize the proposed operators evaluate the credit risk of small new venture' indirect financing.

Step 1. According to w and SVNNs $O_{ij}\left(i = 1,2,3,4,5, j = 1,2,3,4\right)$, we can aggregate all SVNNs O_{ij} by using the DGSVNNWBM (DGSVNNWGBM) operator to derive the SVNNs $O_i\left(i = 1,2,3,4,5\right)$ of the alternative O_i. The aggregating results are in Table 1.

Table 1. The aggregating results of strategic suppliers by the DGSVNNWBM and DGSVNNWGBM ($R=(1,1,1,1).$)

Alternatives	DGSVNNWBM
O1	(0.5720,0.6135,0.2929)
O2	(0.8157,0.5549,0.3423)
O3	(0.6253,0.5980,0.3033)
O4	(0.6377,0.4583,0.3888)
O5	(0.6431,0.7999,0.2927)

Step 2. According to the Table 1 and the scores of the enterprises are shown in Table 2.

Table 2. The scores of the enterprises

Alternatives	DGSVNNWBM
O1	0.5774
O2	0.6617
O3	0.5969
O4	0.6191
O5	0.5390

Step 3. According to the Table 2 and the scores, the order of the enterprises is listed in Table 3, and the best enterprises is O_2.

Table 3. Order of the enterprises

	Order
DGSVNNWBM	$O_2>O_4>O_3>O_1>O_5$

4.2. Influence Analysis

To show the effects on the ranking results by altering the parameters of DGSVNNWBM operator, the corresponding results are shown in Tables 4.

Table 4. Order for different parameters of DGSVNNWBM

R	$S(O_1)$	$S(O_2)$	$S(O_3)$	$S(O_4)$	$S(O_5)$	Order
$(1,1,1,1)$	0.4441	0.5284	0.4636	0.4858	0.4057	$O_2>O_4>O_3>O_1>O_5$
$(2,2,2,2)$	0.6590	0.7493	0.6750	0.7047	0.6215	$O_2>O_4>O_3>O_1>O_5$
$(3,3,3,3)$	0.7170	0.8016	0.7284	0.7549	0.6985	$A_2>A_4>A_3>A_1>A_5$
$(4,4,4,4)$	0.7397	0.8179	0.7472	0.7720	0.7344	$O_2>O_4>O_3>O_1>O_5$
$(5,5,5,5)$	0.7510	0.8240	0.7558	0.7804	0.7545	$O_2>O_4>O_3>O_5>O_1$
$(6,6,6,6)$	0.7578	0.8267	0.7604	0.7860	0.7674	$O_2>O_4>O_5>O_3>O_1$
$(7,7,7,7)$	0.7623	0.8281	0.7632	0.7904	0.7762	$O_2>O_4>O_5>O_3>O_1$
$(8,8,8,8)$	0.7656	0.8289	0.7652	0.7944	0.7827	$O_2>O_4>O_5>O_1>O_3$
$(9,9,9,9)$	0.7681	0.8295	0.7667	0.7980	0.7876	$O_2>O_4>O_5>O_1>O_3$
$(10,10,10,10)$	0.7700	0.8300	0.7678	0.8013	0.7915	$O_2>O_4>O_5>O_1>O_3$

5. Conclusion

In this paper, we focused on SVNN information aggregation operators, as well as their application in MADM. To aggregate the SVNNs, the DGSVNNWBM is used to solve the MADM problems. At the end of this study, we use an applicable example for credit risk evaluation of small new venture' indirect financing to show applicability of this operator, meanwhile, the analysis of the parameters takes different values also have been studied. In subsequent studies, we shall expand the proposed models to other uncertain and fuzzy MADM problems [40-50].

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References

[1] T. Rashid, S. Faizi, S. Zafar, Outranking method for intuitionistic 2-tuple fuzzy linguistic information model in group decision making, Soft Computing, 23 (2019) 6145-6155.

[2] D.F. Li, S.P. Wan, Minimum Weighted Minkowski Distance Power Models for Intuitionistic Fuzzy Madm with Incomplete Weight Information, International Journal of Information Technology & Decision Making, 16 (2017) 1387-1408.

[3] G.F. Yu, D.F. Li, J.M. Qiu, Y.F. Ye, Application of satisfactory degree to interval-valued intuitionistic fuzzy multi-attribute decision making, Journal of Intelligent & Fuzzy Systems, 32 (2017) 1019-1028.

[4] J.C. Liu, D.F. Li, TOPSIS-Based Nonlinear-Programming Methodology for Multi-attribute Decision Making With Interval-Valued Intuitionistic Fuzzy Sets (vol 18, pg 299, 2010), Ieee Transactions on Fuzzy Systems, 26 (2018) 391-391.

[5] L.A. Zadeh, Fuzzy Sets, in: Information and Control, 1965, pp. 338-356.

[6] K.T. Atanassov, Intuitionistic fuzzy sets, Fuzzy Sets and Systems, 20 (1986) 87-96.

[7] B.D. Rouyendegh, The Intuitionistic Fuzzy ELECTRE model, International Journal of Management Science and Engineering Management, 13 (2018) 139-145.

[8] S.M. Chen, S.H. Cheng, T.C. Lan, Multicriteria decision making based on the TOPSIS method and similarity measures between intuitionistic fuzzy values, Information Sciences, 367 (2016) 279-295.

[9] J.W. Gan, L. Luo, Using DEMATEL and Intuitionistic Fuzzy Sets to Identify Critical Factors Influencing the Recycling Rate of End-Of-Life Vehicles in China, Sustainability, 9 (2017).

[10] Y.D. He, Z. He, H. Huang, Decision making with the generalized intuitionistic fuzzy power interaction averaging operators, Soft Computing, 21 (2017) 1129-1144.

[11] Z.N. Hao, Z.S. Xu, H. Zhao, R. Zhang, Novel intuitionistic fuzzy decision making models in the framework of decision field theory, Information Fusion, 33 (2017) 57-70.

[12] F.F. Jin, Z.W. Ni, H.Y. Chen, Y.P. Li, Approaches to group decision making with intuitionistic fuzzy preference relations based on multiplicative consistency, Knowledge-Based Systems, 97 (2016) 48-59.

[13] R. Krishankumar, S.R. Arvinda, A. Amrutha, J. Premaladha, K.S. Ravichandran, Ieee, A decision making framework under intuitionistic fuzzy environment for solving cloud vendor selection problem, 2017.

[14] T.T. Bao, X.L. Xie, P.Y. Long, Z.K. Wei, MADM method based on prospect theory and evidential reasoning approach with unknown attribute weights under intuitionistic fuzzy environment, Expert Systems with Applications, 88 (2017) 305-317.

[15] P. Gupta, M.K. Mehlawat, N. Grover, W. Chen, Modified intuitionistic fuzzy SIR approach with an application to supplier selection, Journal of Intelligent & Fuzzy Systems, 32 (2017) 4431-4441.

[16] H. Garg, Generalized intuitionistic fuzzy multiplicative interactive geometric operators and their application to multiple criteria decision making, International Journal of Machine Learning and Cybernetics, 7 (2016) 1075-1092.

[17] P. Gupta, H.D. Arora, P. Tiwari, Generalized Entropy for Intuitionistic Fuzzy Sets, Malaysian Journal of Mathematical Sciences, 10 (2016) 209-220.

[18] L. Xiao, S. Zhang, G. Wei, J. Wu, C. Wei, Y. Guo, Y. Wei, Green supplier selection in steel industry with intuitionistic fuzzy Taxonomy method, Journal of Intelligent & Fuzzy Systems, 39 (2020) 7247-7258.

[19] M. Li, C. Wu, A Distance Model of Intuitionistic Fuzzy Cross Entropy to Solve Preference Problem on Alternatives, Mathematical Problems in Engineering, (2016).

[20] S. Cali, S.Y. Balaman, A novel outranking based multi criteria group decision making methodology integrating ELECTRE and VIKOR under intuitionistic fuzzy environment, Expert Systems with Applications, 119 (2019) 36-50.

[21] X.J. Gou, Z.S. Xu, Q. Lei, New operational laws and aggregation method of intuitionistic fuzzy information, Journal of Intelligent & Fuzzy Systems, 30 (2016) 129-141.

[22] M.S. Khan, Q.M.D. Lohani, Ieee, A Similarity Measure For Atanassov Intuitionistic Fuzzy Sets and its Application to Clustering, 2016.

[23] P. Li, J. Liu, S.F. Liu, X. Su, J. Wu, Grey Target Method for Intuitionistic Fuzzy Decision Making Based on Grey Incidence Analysis, Journal of Grey System, 28 (2016) 96-109.

[24] P. Liu, J. Liu, S.-M. Chen, Some intuitionistic fuzzy Dombi Bonferroni mean operators and their application to multi-attribute group decision making, Journal of the Operational Research Society, 69 (2018) 1-24.

[25] W.K. Zhang, Y.B. Ju, X.Y. Liu, Interval-valued intuitionistic fuzzy programming technique for multicriteria group decision making based on Shapley values and incomplete preference information, Soft Computing, 21 (2017) 5787-5804.

[26] H. Wang, F. Smarandache, Y.Q. Zhang, R. Sunderraman, Interval Neutrosophic Sets and Logic: Theory and Applications in Computing, Hexis: Phoenix, AZ, USA, (2005).

[27] H. Wang, F. Smarandache, Y.Q. Zhang, R. Sunderraman, Single valued neutrosophic sets, Multispace Multistruct, (2010) 410-413.

[28] J. Ye, Vector similarity measures of simplified neutrosophic sets and their application in multicriteria decision making, International Journal of Fuzzy Systems, 16 (2014) 204-211.

[29] P.D. Liu, Y.M. Wang, Multiple attribute decision-making method based on Single-valued neutrosophic normalized weighted Bonferroni mean, Neural Computing & Applications, 25 (2014) 2001-2010.

[30] J. Ye, Single valued neutrosophic cross-entropy for multicriteria decision making problems, Applied Mathematical Modelling, 38 (2014) 1170-1175.

[31] E.K. Zavadskas, R. Bausys, M. Lazauskas, Sustainable Assessment of Alternative Sites for the Construction of a Waste Incineration Plant by Applying WASPAS Method with Single-valued Neutrosophic Set, Sustainability, 7 (2015) 15923-15936.

[32] J. Ye, Improved Cross Entropy Measures of Single Valued Neutrosophic Sets and Interval Neutrosophic Sets and Their Multicriteria Decision Making Methods, Cybernetics and Information Technologies, 15 (2015) 13-26.

[33] P. Biswas, S. Pramanik, B.C. Giri, TOPSIS method for multi-attribute group decision-making under Single-valued neutrosophic environment, Neural Computing & Applications, 27 (2016) 727-737.

[34] P.D. Liu, The Aggregation Operators Based on Archimedean t-Conorm and t-Norm for Single-valued Neutrosophic Numbers and their Application to Decision Making, International Journal of Fuzzy Systems, 18 (2016) 849-863.

[35] J.Q. Chen, J. Ye, Some Single-valued Neutrosophic Dombi Weighted Aggregation Operators for Multiple Attribute Decision-Making, Symmetry-Basel, 9 (2017).

ISSN: 2688-9323

[36] E.K. Zavadskas, R. Bausys, B. Juodagalviene, I. Garnyte-Sapranaviciene, Model for residential house element and material selection by neutrosophic MULTIMOORA method, Engineering Applications of Artificial Intelligence, 64 (2017) 315-324.

[37] R. Sahin, P.D. Liu, Maximizing deviation method for neutrosophic multiple attribute decision making with incomplete weight information, Neural Computing & Applications, 27 (2016) 2017-2029.

[38] R.T. Zhang, J. Wang, X.M. Zhu, M.M. Xia, M. Yu, Some Generalized Pythagorean Fuzzy Bonferroni Mean Aggregation Operators with Their Application to Multiattribute Group Decision-Making, Complexity, 2017 (2017) 5937376.

[39] J. Wang, X.Y. Tang, G.W. Wei, Models for multiple attribute decision-making with dual generalized Single-valued neutrosophic bonferroni mean operators, Algorithms, 11 (2018) 2.

[40] Z.P. Chen, W. Yang, A new multiple attribute group decision making method in intuitionistic fuzzy setting, Applied Mathematical Modelling, 35 (2011) 4424-4437.

[41] X.F. Zhao, Q.X. Li, G.W. Wei, Some prioritized aggregating operators with linguistic information and their application to multiple attribute group decision making, Journal of Intelligent & Fuzzy Systems, 26 (2014) 1619-1630.

[42] I.E.H. Kremer, S. Evers, P.J. Jongen, T. van der Weijden, I. van de Kolk, M. Hiligsmann, Identification and Prioritization of Important Attributes of Disease-Modifying Drugs in Decision Making among Patients with Multiple Sclerosis: A Nominal Group Technique and Best-Worst Scaling, Plos One, 11 (2016).

[43] J. Ye, Aggregation operators of neutrosophic linguistic numbers for multiple attribute group decision making, Springerplus, 5 (2016).

[44] J. Ye, Multiple attribute group decision making based on interval neutrosophic uncertain linguistic variables, International Journal of Machine Learning and Cybernetics, 8 (2017) 837-848.

[45] Z.M. Liu, P.D. Liu, X. Liang, Multiple Attribute Group Decision-Making Method Based on Generalized Interval-Valued Hesitant Uncertain Linguistic Power Aggregation Operators and Linguistic-Scale Functions, International Journal of Fuzzy Systems, 20 (2018) 1995-2015.

[46] Y. Xu, X.P. Shang, J. Wang, W. Wu, H.Q. Huang, Some q-Rung Dual Hesitant Fuzzy Heronian Mean Operators with Their Application to Multiple Attribute Group Decision-Making, Symmetry-Basel, 10 (2018).

[47] F. Wang, D.Y. Du, J. Zhao, A Novel SIR center dot Choquet Method for Multiple Attributes Group Decision-Making with Interval Grey Linguistic, International Journal of Fuzzy Systems, 21 (2019) 1771-1785.

[48] S.D. Xian, J.H. Chai, H.L. Guo, Z Linguistic-induced ordered weighted averaging operator for multiple attribute group decision-making, International Journal of Intelligent Systems, 34 (2019) 271-296.

[49] C.Q. Zhang, C. Wang, Z.M. Zhang, D.Z. Tian, A novel technique for multiple attribute group decision making in interval-valued hesitant fuzzy environments with incomplete weight information, Journal of Ambient Intelligence and Humanized Computing, 10 (2019) 2429-2445.

[50] X.F. Zhang, X.J. Gou, Z.S. Xu, H.C. Liao, A projection method for multiple attribute group decision making with probabilistic linguistic term sets, International Journal of Machine Learning and Cybernetics, 10 (2019) 2515-2528.