Model for evaluating the building engineering quality with Hesitant Fuzzy Linguistic Information

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Abstract

In this paper, we investigate the multiple attribute decision making problems for evaluating the green building engineering quality with hesitant fuzzy linguistic information. We utilized the hesitant fuzzy linguistic geometric Bonferroni mean (HFLGBM) operator to aggregate the hesitant fuzzy linguistic information corresponding to each alternative and get the overall value of the alternatives, then rank the alternatives and select the most desirable one(s) according to the score function and accuracy function. Finally an illustrative example for evaluating the green building engineering quality with hesitant fuzzy linguistic information has been given to show the developed approach.

Keywords

Multiple Attribute Decision Making (MADM); hesitant fuzzy linguistic information; hesitant fuzzy linguistic geometric Bonferroni mean (HFLGBM) operator; Green Building Assessment.

1. Introduction

Atanassov[1-3]introduced the concept of intuitionistic fuzzy set(IFS), which is a generalization of the concept of fuzzy set[4]. Each element in the IFS is expressed by an ordered pair, and each ordered pair is characterized by a membership degree and a non-membership degree. The sum of the membership degree and the non-membership degree of each ordered pair is less than or equal to 1. The intuitionistic fuzzy set has received more and more attention since its appearance[5-20]. Furthermore, Torra and Narukawa[21] and Torra[22] proposed the hesitant fuzzy set which permits the membership having a set of possible values and discussed the relationship between hesitant fuzzy set and intuitionistic fuzzy set, and showed that the envelope of hesitant fuzzy set is an intuitionistic fuzzy set. Xia and Xu[23] gave an intensive study on hesitant fuzzy information aggregation techniques and their application in decision making. Xu and Xia[24] proposed a variety of distance measures for hesitant fuzzy sets, based on which the corresponding similarity measures can be obtained. Xu and Xia[25] defined the distance and correlation measures for hesitant fuzzy information and then discuss their properties in detail. Xu et al. [26] developed several series of aggregation operators for hesitant fuzzy information with the aid of quasi-arithmetic means. Gu et al.[27] utilized the hesitant fuzzy weighted averaging (HFWA) operator to investigat the evaluation model for risk investment with hesitant fuzzy information. Motivated by the ideal of prioritized aggregation operators[28], Wei[29] developed some prioritized aggregation operators for aggregating hesitant fuzzy information, and then apply them to develop some models for hesitant fuzzy multiple attribute decision making problems in which the attributes are in different priority level. Wei et al.[30] proposed two hesitant fuzzy Choquet integral aggregation operators: hesitant fuzzy choquet ordered averaging (HFCOA) operator and hesitant fuzzy choquet ordered geometric (HFCOG) operator and applied these operators to multiple attribute decision making with hesitant fuzzy information. Wang et al.[31] proposed the generalized hesitant fuzzy hybrid weighted distance (GHFHWD) measure, which is based on the generalized hesitant fuzzy weighted distance (GHFWD) measure and the generalized hesitant fuzzy ordered weighted distance (GHFOWD) measure[24] and studied some desirable properties of the GHFHWD measure. Zhu et al.[32] explored the geometric

Bonferroni mean (GBM) considering both the BM and the geometric mean (GM) under hesitant fuzzy environment. They further defined the hesitant fuzzy geometric Bonferroni mean (HFGBM) and the hesitant fuzzy Choquet geometric Bonferroni mean (HFCGBM). Then they gave the definition of hesitant fuzzy geometric Bonferroni element (HFGBE), which is considered as the basic calculation unit in the HFGBM and reflects the conjunction between two aggregated arguments.

In this paper, we investigate the multiple attribute decision making problems for evaluating the green building engineering quality with hesitant fuzzy linguistic information. We utilized the dependent hesitant fuzzy linguistic geometric Bonferroni mean (DHFLGBM) operator to aggregate the hesitant fuzzy linguistic information corresponding to each alternative and get the overall value of the alternatives, then rank the alternatives and select the most desirable one(s) according to the score function and accuracy function. Finally an illustrative example for evaluating the green building engineering quality with hesitant fuzzy linguistic information has been given to show the developed approach.

2. Preliminarie

Assuming that $S=\{s_i|i=1,2,\cdots,t\}$ refers to a linguistic word set utilizing odd cardinality. On the other hand, we suppose that s_i denotes a possible value for a specific variable, and then this value should follow the following features [33-34]: ①The set is ranked: $s_i > s_j$, if $i > j$; ②There is the negation operator: $neg(s_i) = s_j$ such that $i + j = t + 1$; ③Max operator: $\max(s_i, s_j) = s_i$, if $s_i \geq s_j$; ④Min operator: $\min(s_i, s_j) = s_i$, if $s_i \leq s_j$;.Particularly, S is represented as follows.

$$\begin{aligned} S=\{&s_1 = extremely\ poor, s_2 = very\ poor,\\ &s_3 = poor, s_4 = medium, s_5 = good,\\ &s_6 = very\ good, s_7 = extremely\ good\} \end{aligned}$$

Utilizing the linguistic term set[33-34] and hesitant fuzzy set[35], Lin et al.[36] design some important concepts and important operational rules which is corresponding to the hesitant fuzzy linguistic set.

Definition 1[36]. Given a fixed set X, then a hesitant fuzzy linguistic set (HFLS) on X is according to a function which is exploited to X returns a sunset of $[0,1]$. In order to let the process much simpler, , the HFLS can be represented by the following equation.

$$A = \left(\left\langle x, s_{\theta(x)}, h_A(x)\right\rangle \middle| x \in X\right) \quad (1)$$

where $h_A(x)$ refers to a set of some values which are ranged from zero to one, which is represented as the possible membership degree of the element $x \in X$ to the linguistic set $s_{\theta(x)}$. To be easier, we called $a = \left\langle s_{\theta(x)}, h_A(x)\right\rangle$ a hesitant fuzzy linguistic element (HFLE) and A the set of all HFLEs.

Definition 2[36]. For a HFLE $a = \left\langle s_{\theta(x)}, h_A(x)\right\rangle$, $s(a) = \left(\frac{1}{\#h}\sum_{\gamma\in h}\gamma\right) s_{\theta(x)}$ is named a score function of a, where $\#h$ refers to the number of the elements in h. Supposing that there are two HFLEs, which are a_1 and a_2, when $s(a_1) > s(a_2)$, $a_1 > a_2$ is saisfied; if $s(a_1) = s(a_2)$, $a_1 = a_2$ is satisfied.

In the following, Zhu et al.[37] studied on the geometric Bonferroni mean (GBM) which utilizing both the BM and the geometric mean (GM).

Definition 3[37]. Let $p, q \geq 0$ and $a_i\ (i = 1, 2, \cdots, n)$ refers to a collection of non-negative real numbers. Afterwards, the aggregation functions are defined as follows:

$$GBM^{p,q}\left(a_1,a_2,\cdots,a_n\right)=\frac{1}{p+q}\left(\prod_{\substack{i,j=1\\ i\neq j}}^{n}\left(pa_i+qa_j\right)\right)^{\frac{1}{n(n-1)}} \tag{2}$$

is named the geometric Bonferroni mean (GBM) operator.

Then, Gu et al.[38] defined the hesitant fuzzy linguistic weighted Geometric Bonferroni mean (HFLWGBM) operator.

Definition 4[38]. Assuming that $a_j=\left(s_{\theta(a_j)},h(a_j)\right)$ $(j=1,2,\cdots,n)$ represents a set of HFLEs, and $p,q>0$, $w=\left(w_1,w_2,\cdots,w_n\right)^T$ denotes the weight vector of a_j $(j=1,2,\cdots,n)$, in which w_j indicates the importance degree of a_j, satisfying $w_j>0(j=1,2,\cdots,n)$, and $\sum_{j=1}^{n}w_j=1$. If

$$\text{HFLWGBM}_w^{p,q}\left(a_1,a_2,\cdots,a_n\right)=\left(\frac{1}{p+q}\underset{\substack{i,j=1\\ i\neq j}}{\overset{n}{\otimes}}\left(\left(w_ia_i\right)^p\oplus\left(w_ja_j\right)^p\right)\right)^{\frac{1}{n(n-1)}}$$

$$=\left\langle\left(\frac{1}{p+q}\underset{\substack{i,j=1\\ i\neq j}}{\overset{n}{\otimes}}\left(\left(s_{w_i\theta(a_i)}\right)^p\oplus\left(s_{w_j\theta(a_j)}\right)^q\right)\right)^{\frac{1}{n(n-1)}},\right.$$

$$\left.\left(\bigcup_{\gamma(a_1)\in h(a_1),\gamma(a_2)\in h(a_2),\cdots,\gamma(a_n)\in h(a_n)}\left\{\left(\begin{array}{l}\frac{1}{p+q}\underset{\substack{i,j=1\\ i\neq j}}{\overset{n}{\otimes}}\left(\left(p\gamma(a_i)\right)^{w_i}\oplus\left(q\gamma(a_j)\right)^{w_j}\right)\\ \otimes\left(\left(p\gamma(a_j)\right)^{w_j}\oplus\left(q\gamma(a_i)\right)^{w_i}\right)\end{array}\right)^{\frac{2}{n(n-1)}}\right\}\right\rangle \tag{3}$$

$$=\left\langle\left(\frac{1}{p+q}\underset{\substack{i,j=1\\ i\neq j}}{\overset{n}{\otimes}}\left(\left(s_{w_i\theta(a_i)}\right)^p\oplus\left(s_{w_j\theta(a_j)}\right)^q\right)\right)^{\frac{1}{n(n-1)}},\right.$$

$$\left.\left(\bigcup_{\gamma(a_1)\in h(a_1),\gamma(a_2)\in h(a_2),\cdots,\gamma(a_n)\in h(a_n)}\left\{1-\left(1-\prod_{\substack{i,j=1\\ i\neq j}}^{n}\left(\varepsilon_{i,j}^{w}\right)^{\frac{2}{n(n-1)}}\right)^{\frac{1}{p+q}}\right\}\right\rangle$$

then the $\text{HFLWGBM}_w^{p,q}$ is named as the hesitant fuzzy linguistic weighted Geometric Bonferroni mean (HFLWGBM) operator.

3. Model for Green Building Quality Assessment Integrated Carbon Emissions with Hesitant Fuzzy Linguistic Information

In this section, we shall utilize the hesitant fuzzy linguistic weighted Geometric Bonferroni mean (HFLWGBM) operator to multiple attribute decision making problems for evaluating the green building quality with hesitant fuzzy linguistic information. Let $A=\{A_1,A_2,\cdots,A_m\}$ denoting a discrete set of alternatives, and $G=\{G_1,G_2,\cdots,G_n\}$ means the state of nature. Furthermore, when the decision makers can give some values for the alternative A_i under the state of nature G_j with respect to $s_{\theta_{ij}}$ with anonymity, these values can be represented as a hesitant fuzzy linguistic values $\langle s_{\theta_{ij}}, h_{ij} \rangle$. Suppose that the decision matrix $H = \left(\tilde{h}_{ij}\right)_{m\times n} = \left(\langle s_{\theta_{ij}}, h_{ij} \rangle\right)_{m\times n}$ refers to the hesitant fuzzy linguistic decision matrix, where $\langle s_{\theta_{ij}}, h_{ij} \rangle (i = 1,2,\cdots,m,\ j = 1,2,\cdots,n)$ are in the form of HFLEs.

Next, we use the hesitant fuzzy linguistic weighted Geometric Bonferroni mean (HFLWGBM) operator to the MADM problems for evaluating the green building quality with hesitant fuzzy linguistic information.

Step 1. We exploit the decision information given in matrix H, and the HFLWGBM operator to obtain the overall preference values $a_i\,(i = 1,2,\cdots,m)$ of the green building projects A_i.

Step 2. Computing the scores $S(a_i)\,(i = 1,2,\cdots,m)$ of the hesitant fuzzy linguistic values $a_i\,(i = 1,2,\cdots,m)$ to order the given the green buildings $A_i\,(i = 1,2,\cdots,m)$ and the we can choose the optimal one.

Step 3. Order all the green building projects $A_i\,(i = 1,2,\cdots,m)$ and choose the optimal using the equation $S(a_i)\,(i = 1,2,\cdots,m)$.

Step 4. End.

4. Numerical example

This section presents a numerical example to illustrate the method proposed in this paper. Suppose a school plans to evaluate the green building quality. There is a panel with five possible green building projects $A_i\,(i = 1,2,3,4,5)$ to select. The company selects four attribute to evaluate the five possible green building projects: ①G1 is the energy saving and energy use; ②G2 is the indoor environmental quality; ③G3 is the saving material and material resources; ④G4 is the water saving and water resource utilization. The five possible green building projects $A_i\,(i = 1,2,3,4,5)$ are to be evaluated by using the hesitant fuzzy linguistic numbers by under the above four attributes (whose weighting vector $\omega = (0.2, 0.1, 0.3, 0.4)^T$), and construct, respectively, the decision matrix as listed in the Table 1.

Table 1. Hesitant fuzzy linguistic decision matrix

	G_1	G_2	G_3	G_4
A_1	$< s_2, (0.7,0.8)>$	$<s_3,(0.2,0.5,0.6)>$	$< s_4, (0.2,0.5)>$	$< s_2, (0.2,0.4)>$
A_2	$< s_2, (0.4,0.7)>$	$< s_2, (0.3,0.6,0.8)>$	$< s_2, (0.3,0.4,0.5)>$	$< s_3, (0.3,0.4)>$
A_3	$<s_5,(0.7, 0.9)>$	$< s_5, (0.6,0.8)>$	$< s_2,(0.2,0.3,0.7)>$	$< s_2, (0.4,0.6)>$
A_4	$< s_3, (0.4,0.5)>$	$< s_5, (0.4,0.6)>$	$<s_2,(0.6,0.8)>$	$< s_5, (0.3,0.4)>$
A_5	$< s_5, (0.8,0.9)>$	$< s_2, (0.3,0.7)>$	$<s_5,(0.4,0.5)>$	$< s_3,(0.3,0.4,0.6)>$

In the following, we apply the HFLWGBM operator to MADM problems to evaluate the green building quality of green building projects with hesitant fuzzy linguistic numbers. To get the most desirable green building projects, the following steps are involved:

Step 1. Utilize the HFLWGBM operator, we obtain the overall preference values $\tilde{r}_i$ of the green building projects $A_i\left(i=1,2,\cdots,5\right)$ and Calculate the scores $S\left(a_i\right)\left(i=1,2,3,4,5\right)$ of the overall hesitant fuzzy linguistic values a_i $\left(i=1,2,3,4,5\right)$.

$$S\left(\tilde{h}_1\right)=s_{1.37}, S\left(\tilde{h}_2\right)=s_{3.49}, S\left(\tilde{h}_3\right)=s_{1.21}, S\left(\tilde{h}_4\right)=s_{2.74}, S\left(\tilde{h}_5\right)=s_{3.16}$$

Step 3. Rank all the green building projects $A_i\left(i=1,2,3,4,5\right)$ in accordance with the scores $S\left(\tilde{r}_i\right)$ $\left(i=1,2,\cdots,5\right)$ of the overall hesitant fuzzy linguistic numbers $\tilde{r}_i$ $\left(i=1,2,\cdots,5\right)$: $A_2 \succ A_5 \succ A_4 \succ A_1 \succ A_3$, and thus the most desirable green building project is A_2.

5. Conclusion

In this paper, we investigate the multiple attribute decision making problems for evaluating the green building engineering quality with hesitant fuzzy linguistic information. We utilized the hesitant fuzzy linguistic geometric Bonferroni mean (HFLGBM) operator to aggregate the hesitant fuzzy linguistic information corresponding to each alternative and get the overall value of the alternatives, then rank the alternatives and select the most desirable one(s) according to the score function and accuracy function. Finally an illustrative example for evaluating the green building engineering quality with hesitant fuzzy linguistic information has been given to show the developed approach.

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