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Model for evaluating the brand extension of biological medicine enterprises with multigranularity linguistic information

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ABSTRACT

In this paper, we study on the multiple attribute group decision making problems for evaluating the brand extension of biological medicine enterprises with multigranularity linguistic information. Firstly, the multigranularity linguistic information is transformed into triangular fuzzy numbers. Then, we extend the grey relational analysis (GRA) procedure for multiple attribute group decision making with multigranularity linguistic information. According to the concept of the GRA, a fuzzy relative relational degree is defined to determine the ranking order of all alternatives by calculating the degree of fuzzy grey relational coefficient to both the fuzzy positive-ideal solution (FPIS) and fuzzy negative-ideal solution (FNIS) simultaneously. Finally, an example for evaluating the brand extension of biological medicine enterprises is given to show the feasibility and effectiveness of the proposed method.

KEYWORDS

Grey relational analysis (GRA); linguistic variables; triangular fuzzy numbers; Multiple attribute group decision making (MAGDM); Brand extension; Biological medicine enterprises.

INTRODUCTION

Brand extension not only can help companies penetrate new markets quickly, but also can help companies improve brand value, and therefore it has drawn a lot of research attention in the area of marketing. Along the advancement of technology and the development of labor division in the society, the difference of quality of different brands in the same class becomes smaller and smaller, and the role of symbolic value on brand extension becomes more and more important. As for brand extension, it has been in the frontier of marketing theory and brand research, and the evaluation of brand extension is an important branch. By evaluating of brand extension, extension efficiency will be enhanced and extension risk will be avoided, which is with practical significance. During the past thirty years, scholars have devoted themselves to explore factors affecting brand extension, the evaluation system is developing with substantial relevant researches, but little service-specific research has focused on this domain so far. As the service industry accounts for an ever-growing share of the global economy, service management is becoming increasingly important. Little is known, however, about the extent to which brand equity transfers to unrelated categories in a services context, so further studies on evaluation theories and methods of service brand extension are valuable.

Multiple attribute decision making is a usual task in human activities. It consists of finding the most preferred alternative from a given alternative set. The increasing complexity of the socio-economic environment makes it less and less possible for a single decision maker to consider all relevant aspects of a problem. As a result, many decision making processes take place in group settings in the real life situation. However, under many conditions, numerical values are inadequate or insufficient to model real-life decision problems. Indeed, human judgments including preference information may be stated in linguistic terms. Thus, multiple attribute group decision making (MAGDM) problems under linguistic environment is an interesting research topic having received more and more attention from researchers during the last several years[1-15]. In the process of MAGDM with linguistic information, sometimes, the attribute values and attribute weights take the form of multigranularity linguistic information because of different decision makers' different preference.

In this paper, we study on the multiple attribute group decision making problems for evaluating the brand extension of biological medicine enterprises with multigranularity linguistic information. Firstly, the multigranularity linguistic information is transformed into triangular fuzzy numbers. Then, we extend the grey relational analysis (GRA) procedure for multiple attribute group decision making with multigranularity linguistic information. According to the concept of the GRA, a fuzzy relative relational degree is defined to determine the ranking order of all alternatives by calculating the degree of fuzzy grey relational coefficient to both the fuzzy positive-ideal solution (FPIS) and fuzzy negative-ideal solution (FNIS) simultaneously. Finally, an example for evaluating the brand extension of biological medicine enterprises is given to show the feasibility and effectiveness of the proposed method.

PRELIMINARIES

In the following, we briefly review some basic definitions and notations of linguistic information and triangular fuzzy numbers.

Let $S^t=\left\{s_i^t \left| i=0,1,\cdots,t-1\right.\right\}$ be a linguistic term set with odd cardinality. Any label, s_i^t represents a possible value for a linguistic variable, and it should satisfy the following characteristics[8-9]:

(1) The set is ordered: $s_i^t > s_j^t$, if $i>j$; (2) Max operator: $\max\left(s_i^t,s_j^t\right)=s_i^t$, if $s_i^t \ge s_j^t$; (3) Min operator: $\min\left(s_i^t,s_j^t\right)=s_i^t$, if $s_i^t \le s_j^t$. For example, S can be defined as

$$\begin{aligned} S=\{&s_0=extremely\ poor(EP), s_1=very\ poor(VP), s_2=poor(P), s_3=medium(M),\\ &s_4=good(G), s_5=very\ good(VG), s_6=extremely\ good(EG)\}\end{aligned}$$

Definition 1[16]. A triangular fuzzy numbers $\tilde{a}$ can be defined by a triplet $\left(a^L,a^M,a^U\right)$. The membership function $\mu_{\tilde{a}}\left(x\right)$ is defined as:

$$\mu_{\tilde{a}}\left(x\right)=\begin{cases} 0, & x<a^L, \\ \dfrac{x-a^L}{a^M-a^L}, & a^L \le x \le a^M, \\ \dfrac{x-a^U}{a^M-a^U}, & a^M \le x \le a^U, \\ 0, & x \ge a^U. \end{cases} \quad (1)$$

where $0 < a^L \le a^M \le a^U$, a^L and a^U stand for the lower and upper values of the support of $\tilde{a}$,respectively, and a^M for the modal value.

Definition 2[17]. A fuzzy set $\tilde{A}$ of the universe of discourse X is convex if and only if for all x_1, x_2 in X ,

$$\mu_{\tilde{A}}\left(\lambda x_1 + (1-\lambda) x_2\right) \ge Min\left(\mu_{\tilde{A}}(x_1), \mu_{\tilde{A}}(x_2)\right), \lambda \in [0,1] \quad \textbf{(2)}$$

Definition 3[17]. Basic operational laws related to triangular fuzzy numbers:

$$\tilde{a} \oplus \tilde{b} = \left[a^L, a^M, a^U\right] \oplus \left[b^L, b^M, b^U\right] = \left[a^L + b^L, a^M + b^M, a^U + b^U\right] \quad \textbf{(3)}$$

$$\tilde{a} \otimes \tilde{b} = \left[a^L, a^M, a^U\right] \otimes \left[b^L, b^M, b^U\right] = \left[a^L b^L, a^M b^M, a^U b^U\right] \quad \textbf{(4)}$$

Definition 4[17]. Let $\tilde{a} = \left[a^L, a^M, a^U\right]$ and $\tilde{b} = \left[b^L, b^M, b^U\right]$ be two triangular fuzzy numbers, then the vertex method is defined to calculate the distance between them as

$$\left\|\tilde{a} - \tilde{b}\right\| = \sqrt{\frac{1}{3}\left[\left(a^L - b^L\right)^2 + \left(a^M - b^M\right)^2 + \left(a^U - b^U\right)^2\right]} \quad \textbf{(5)}$$

The linguistic assessment information can be expressed in positive triangular fuzzy numbers[18]. Given any linguistic assessment information s_r^t, the rth $\left(r = 0,1,\cdots,t-1\right)$ linguistic term of t multigranularity linguistic assessment information sets S^t, can be expressed in triangular fuzzy numbers as follows:

$$\tilde{a} = \left(a^L, a^M, a^U\right) = \left(\max\left((r-1)/(t-1), 0\right), r/(t-1), \min\left((r+1)/(t-1), 1\right)\right) \quad \textbf{(6)}$$

For example, $S^t\left(t = 5,7,9\right)$ can be expressed in triangular fuzzy numbers in TABLE 1-3.

TABLE 1 : The linguistic terms in the linguistic sets S^5 and their corresponding triangular fuzzy numbers

linguistic terms	triangular fuzzy numbers
s_0^5	(0,0,0.25)
s_1^5	(0,0.25,0.5)
s_2^5	(0.25,0.5,0.75)
s_3^5	(0.5,0.75,1)
s_4^5	(0.75,1,1)

TABLE 2 : The linguistic terms in the linguistic sets S^7 and their corresponding triangular fuzzy numbers

linguistic terms	triangular fuzzy numbers
s_0^7	(0,0,0.17)
s_1^7	(0,0.17,0.33)
s_2^7	(0.17,0.33,0.5)
s_3^7	(0.33,0.5,0.67)
s_4^7	(0.5,0.67,0.83)
s_5^7	(0.67,0.83,1)
s_6^7	(0.83,1,1)

TABLE 3 : The linguistic terms in the linguistic sets S^9 and their corresponding triangular fuzzy numbers

linguistic terms	triangular fuzzy numbers
s_0^9	(0,0,0.13)
s_1^9	(0,0.13,0.25)
s_2^9	(0.13,0.25,0.38)
s_3^9	(0.25,0.38,0.5)
s_4^9	(0.38,0.5,0.63)
s_5^9	(0.5,0.63,0.75)
s_6^9	(0.63,0.75,0.88)
s_7^9	(0.75,0.88,1)
s_8^9	(0.88,1,1)

THE PROPOSED METHOD

GRA method was originally developed by Deng[19-26] and has been widely used to solve the uncertainty problems under the discrete data and information incompleteness. In addition, GRA method is one of the very popular methods to analyze various relationships among the discrete data sets and make decisions in multiple attribute situations. The major advantages of the GRA method are that the results are based on the original data, the calculations are simple and straightforward, and, finally, it is one of the best methods to make decisions under business environment. A systematic approach to extend the GRA method to solve the MAGDM problems with multigranularity linguistic assessment information is proposed in this section.

Suppose that in a MAGDM problem, let $A=\{A_1,A_2,\cdots,A_m\}$ be a discrete set of alternatives, $G=\{G_1,G_2,\cdots,G_n\}$ be the set of attributes, $D=\{D_1,D_2,\cdots,D_p\}$ be the set of decision makers. Suppose that $R_k=\left(r_{ij}^{t(k)}(k)\right)_{m\times n}$ is the group decision making matrix, where $r_{ij}^{t(k)}(k)\in S$ is a preference values, which take the form of linguistic of $t(k)$ multigranularity linguistic assessment information set, given by the decision maker $D_k\in D$, for the alternative $A_i\in A$ with respect to the attribute $G_j\in G$, $W^{(k)}=\left(w_1^{(k)},w_2^{(k)},\cdots,w_n^{(k)}\right)$ is the weighting vector of the attributes $G_j\,(j=1,2,\cdots,n)$ given by the decision maker $D_k\in D$, where $w_j^{(k)}$ $(j=1,2,\cdots,n,k=1,2,\cdots,p)\in S$ is a preference values, which take the form of linguistic variable of $t(k)$ multigranularity linguistic assessment information set, given by the decision maker $D_k\in D$ with respect to the attribute $G_j\in G$.

In the following, we shall utilize the GRA method to solve the MAGDM problems with multigranularity linguistic assessment information.

Step 1. According to Eq.(6), the linguistic assessment information $r_{ij}^{t(k)}(k)$ and the weight of attribute $w_j^{(k)}$ are expressed in triangular fuzzy numbers $d_{ij}(k)=\left(d_{ij}^L(k),d_{ij}^M(k),d_{ij}^U(k)\right)$ and $v_j(k)=\left(v_j^L(k),v_j^M(k),v_j^U(k)\right)$. So, the matrix of multigranularity linguistic assessment information $R_k=\left(r_{ij}^{t(k)}(k)\right)_{m\times n}$ and $W^{(k)}$ are unified into the matrix of triangular fuzzy numbers $D_{ij}(k)\left(d_{ij}(k)=\left(d_{ij}^L(k),d_{ij}^M(k),d_{ij}^U(k)\right)\right)$ and $V(k)\left(v_j(k)=\left(v_j^L(k),v_j^M(k),v_j^U(k)\right)\right)$.

Step 2. Assuming that a decision group has p experts, then the weight of the attribute and the attribute values of alternatives with respect to each attribute can be calculated as.

$$d_{ij} = \frac{1}{p}\left(d_{ij}(1) \oplus d_{ij}(2) \oplus \cdots \oplus d_{ij}(p)\right), v_j = \frac{1}{p}\left(v_j(1) \oplus v_j(2) \oplus \cdots \oplus v_j(p)\right) \quad \textbf{(6)}$$

where $d_{ij}(k)$ and $v_j(k)$ are the attribute values and the importance weight of the p th DM.
As stated above, a FMADM problem which can be concisely expressed in matrix format as

$$\tilde{D} = \begin{bmatrix} \tilde{d}_{11} & \tilde{d}_{12} & \cdots & \tilde{d}_{1n} \\ \tilde{d}_{21} & \tilde{d}_{22} & \cdots & \tilde{d}_{2n} \\ \vdots & \vdots & \cdots & \vdots \\ \tilde{d}_{m1} & \tilde{d}_{m2} & \cdots & \tilde{d}_{mn} \end{bmatrix}, \tilde{V} = \left[\tilde{v}_1, \tilde{v}_2, \cdots, \tilde{v}_n\right]$$

where $\tilde{d}_{ij} = \left(d_{ij}^L, d_{ij}^M, d_{ij}^U\right)$ and $\tilde{v}_j = \left(v_j^L, v_j^M, v_j^U\right)$ are triangular fuzzy numbers.

Step 3. Considering the different importance of each attribute, we can construct the weighted triangular fuzzy decision matrix as

$$\tilde{Y} = \left[\tilde{y}_{ij}\right]_{m\times n} = \left[\tilde{d}_{ij} \otimes \tilde{v}_j\right]_{m\times n}, i = 1,2,\cdots,m, j = 1,2,\cdots,n. \quad \textbf{(7)}$$

Step 4. Defining the fuzzy positive-ideal solution (FPIS,Y^+) and fuzzy negative-ideal solution (FNIS,Y^-) as

$$Y^+ = \left[\tilde{y}_1^+, \tilde{y}_2^+, \cdots, \tilde{y}_n^+\right], Y^- = \left[\tilde{y}_1^-, \tilde{y}_2^-, \cdots, \tilde{y}_n^-\right]$$

where

$$\tilde{y}_j^+ = (\max_i y_{ij}^L, \max_i y_{ij}^M, \max_i y_{ij}^U), \tilde{y}_j^- = (\min_i y_{ij}^L, \min_i y_{ij}^M, \min_i y_{ij}^U).$$

Step 5. Calculating the fuzzy grey relational coefficient of each alternative from FPIS and FNIS using the following equation, respectively:

$$\xi_{ij}^+ = \frac{\min\limits_{1\le i\le m}\min\limits_{1\le j\le n}\left\|\tilde{y}_j^+ - \tilde{y}_{ij}\right\| + \rho \max\limits_{1\le i\le m}\max\limits_{1\le j\le n}\left\|\tilde{y}_j^+ - \tilde{y}_{ij}\right\|}{\left\|\tilde{y}_j^+ - \tilde{y}_{ij}\right\| + \rho \max\limits_{1\le i\le m}\max\limits_{1\le j\le n}\left\|\tilde{y}_j^+ - \tilde{y}_{ij}\right\|} \quad \textbf{(8)}$$

$$\xi_{ij}^- = \frac{\min\limits_{1\le i\le m}\min\limits_{1\le j\le n}\left\|\tilde{y}_{ij} - \tilde{y}_j^-\right\| + \rho \max\limits_{1\le i\le m}\max\limits_{1\le j\le n}\left\|\tilde{y}_{ij} - \tilde{y}_j^-\right\|}{\left\|\tilde{y}_{ij} - \tilde{y}_j^-\right\| + \rho \max\limits_{1\le i\le m}\max\limits_{1\le j\le n}\left\|\tilde{y}_{ij} - \tilde{y}_j^-\right\|} \quad \textbf{(9)}$$

where the identification coefficient $\rho = 0.5$.

Step 6. Calculating the degree of fuzzy grey relational coefficient of each alternative from FPIS and FNIS using the following equation, respectively:

$$\xi_i^+ = \frac{1}{n}\sum_{j=1}^{n}\xi_{ij}^+, \xi_i^- = \frac{1}{n}\sum_{j=1}^{n}\xi_{ij}^-, i = 1,2,\cdots,m. \quad \textbf{(10)}$$

Step 7. Calculating the fuzzy relative relational degree of each alternative from FPIS using the following equation,

$$\xi_i = \xi_i^+ \Big/ \left(\xi_i^- + \xi_i^+\right), i = 1,2,\cdots,m. \quad \textbf{(11)}$$

Step 8. According to the fuzzy relative relational degree, the ranking order of all alternatives can be determined. If any alternative has the highest ξ_i value, then, it is the most important alternative.

NUMERICAL EXAMPLE

In this section, we shall give a numerical example to show the multiple attribute group decision making problems for evaluating the brand extension of biological medicine enterprises with multigranularity linguistic information. There are five biological medicine enterprises to be evaluated the brand extension according to the following four attributes: ①G_1 is the brand asset value; ②G_2 is the relation between core brand and extensive product; ③G_3 is the internal environment factors; ④G_4 is the external environment factors. The five possible biological medicine enterprises $A_i\left(i=1,2,\cdots,5\right)$ are to be evaluated using the multi-granularity linguistic term set by the three decision makers $D_k\left(k=1,2,3\right)$ under the above four attributes, and construct, respectively, the multi-granularity linguistic assessment information matrixes and attribute weight given by experts are shown as follows:

$$R_1=\begin{bmatrix} s_3^5 & s_4^5 & s_1^5 & s_2^5 \\ s_4^5 & s_1^5 & s_4^5 & s_2^5 \\ s_3^5 & s_4^5 & s_0^5 & s_2^5 \\ s_2^5 & s_4^5 & s_1^5 & s_3^5 \\ s_3^5 & s_2^5 & s_4^5 & s_2^5 \end{bmatrix}, R_2=\begin{bmatrix} s_5^7 & s_4^7 & s_6^7 & s_4^7 \\ s_4^7 & s_5^7 & s_3^7 & s_6^7 \\ s_3^7 & s_4^7 & s_6^7 & s_2^7 \\ s_5^7 & s_4^7 & s_5^7 & s_6^7 \\ s_4^7 & s_6^7 & s_3^7 & s_5^7 \end{bmatrix}, R_3=\begin{bmatrix} s_6^9 & s_5^9 & s_3^9 & s_8^9 \\ s_4^9 & s_7^9 & s_3^9 & s_5^9 \\ s_6^9 & s_4^9 & s_7^9 & s_3^9 \\ s_5^9 & s_7^9 & s_3^9 & s_2^9 \\ s_8^9 & s_3^9 & s_7^9 & s_4^9 \end{bmatrix}$$

$$w(2)=\begin{bmatrix} s_4^5 & s_1^5 & s_2^5 & s_3^5 \end{bmatrix}, w(1)=\begin{bmatrix} s_6^7 & s_3^7 & s_5^7 & s_2^7 \end{bmatrix}, w(3)=\begin{bmatrix} s_5^9 & s_8^9 & s_6^9 & s_3^9 \end{bmatrix}$$

The proposed method is currently applied to solve this problem and the computational procedure is summarized as follows:

Step 1. Converting the linguistic evaluation (shown in TABLES 1-3) into triangular fuzzy numbers, and then, constructing the fuzzy decision matrix $\tilde{X}$ and determining the fuzzy weight of each attribute as matrix $\tilde{W}$.

$$\tilde{X}=\begin{bmatrix} [0.600,0.777,0.960] & [0.583,0.767,0.860] & [0.360,0.543,0.667] & [0.543,0.723,0.860] \\ [0.543,0.723,0.820] & [0.473,0.653,0.833] & [0.443,0.627,0.723] & [0.527,0.710,0.833] \\ [0.487,0.667,0.850] & [0.543,0.723,0.820] & [0.527,0.627,0.750] & [0.223,0.403,0.583] \\ [0.473,0.653,0.833] & [0.667,0.850,0.943] & [0.307,0.487,0.667] & [0.487,0.667,0.793] \\ [0.627,0.807,0.943] & [0.443,0.627,0.750] & [0.610,0.793,0.890] & [0.433,0.610,0.793] \end{bmatrix}$$

$$\tilde{W}=\begin{bmatrix} [0.367,0.487,0.592] & [0.370,0.492,0.564] & [0.306,0.427,0.519] & [0.307,0.426,0.529] \end{bmatrix}$$

Step 2. Constructing the weighted triangular fuzzy decision matrix as $\tilde{Y}$.

$$\tilde{Y}=\begin{bmatrix} [0.220,0.378,0.569] & [0.216,0.377,0.485] & [0.110,0.232,0.346] & [0.167,0.308,0.455] \\ [0.199,0.352,0.486] & [0.175,0.322,0.470] & [0.135,0.267,0.375] & [0.162,0.302,0.441] \\ [0.178,0.324,0.503] & [0.201,0.356,0.463] & [0.161,0.267,0.389] & [0.068,0.172,0.309] \\ [0.174,0.318,0.494] & [0.247,0.418,0.532] & [0.094,0.208,0.346] & [0.149,0.284,0.420] \\ [0.230,0.393,0.559] & [0.164,0.308,0.423] & [0.186,0.338,0.462] & [0.133,0.260,0.420] \end{bmatrix}$$

Step 3. Determining FPIS and FNIS as:

$$\tilde{Y}^{+}=\begin{bmatrix} [0.230,0.393,0.569] & [0.247,0.418,0.532] & [0.186,0.338,0.462] & [0.167,0.308,0.455] \end{bmatrix}$$
$$\tilde{Y}^{-}=\begin{bmatrix} [0.174,0.318,0.486] & [0.164,0.308,0.423] & [0.094,0.208,0.346] & [0.068,0.172,0.309] \end{bmatrix}$$

Step 4. Calculating the fuzzy grey relational coefficient of each biological medicine enterprise from FPIS and FNIS

$$\xi^{+}=\left(\xi_{ij}^{+}\right)_{5\times 4}=\begin{bmatrix} 0.864 & 0.615 & 0.389 & 1.000 \\ 0.534 & 0.451 & 0.475 & 0.874 \\ 0.509 & 0.517 & 0.515 & 0.333 \\ 0.482 & 1.000 & 0.360 & 0.707 \\ 0.919 & 0.388 & 1.000 & 0.619 \end{bmatrix}, \xi^{-}=\left(\xi_{ij}^{-}\right)_{5\times 4}=\begin{bmatrix} 0.498 & 0.512 & 0.792 & 0.333 \\ 0.723 & 0.690 & 0.586 & 0.349 \\ 0.851 & 0.607 & 0.527 & 1.000 \\ 0.934 & 0.388 & 1.000 & 0.386 \\ 0.484 & 1.000 & 0.360 & 0.417 \end{bmatrix}$$

Step 5. Calculating the degree of fuzzy grey relational coefficient of each biological medicine enterprise from FPIS and FNIS

$$\xi_1^{+}=0.717, \xi_2^{+}=0.584, \xi_3^{+}=0.469, \xi_4^{+}=0.637, \xi_5^{+}=0.731$$

$$\xi_1^{-}=0.501, \xi_2^{-}=0.450, \xi_3^{-}=0.341, \xi_4^{-}=0.517, \xi_5^{-}=0.502.$$

Step 6. Calculating the fuzzy relative relational degree of each biological medicine enterprise from FPIS

$$\xi_1=0.589, \xi_2=0.565, \xi_3=0.579, \xi_4=0.552, C_5=0.593.$$

Step 7. According to the fuzzy relative relational degree, the ranking order of the five alternatives is: $A_5 \succ A_1 \succ A_3 \succ A_2 \succ A_4$. Thus, the most desirable biological medicine enterprise is A_5.

CONCLUSION

In this paper, we study on the multiple attribute group decision making problems for evaluating the brand extension of biological medicine enterprises with multigranularity linguistic information. Firstly, the multigranularity linguistic information is transformed into triangular fuzzy numbers. Then, we extend the grey relational analysis (GRA) procedure for multiple attribute group decision making with multigranularity linguistic information. According to the concept of the GRA, a fuzzy relative relational degree is defined to determine the ranking order of all alternatives by calculating the degree of fuzzy grey relational coefficient to both the fuzzy positive-ideal solution (FPIS) and fuzzy negative-ideal solution (FNIS) simultaneously. Finally, an example for evaluating the brand extension of biological medicine enterprises is given to show the feasibility and effectiveness of the proposed method.

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