

Expert Decision Making Method Based On Uncertain Linguistic Variables

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Abstract- In this paper, we propose an expert decision making method, UL-TOPSIS. Through giving experts the flexibility of evaluation, they can choose two items of linguistic variables by the multiple-choice method, with an interval range of uncertain linguistic variables to express their real thinking. The method is also used to resolve the problem of too wide range of an individual expert opinion or too large differences between experts opinions. We hope that the new method can capture the opinions of experts better, integrate the opinions of all experts appropriately, and make more accurate decisions for decision makers.

Keywords- expert decision making; fuzzy sets theory; uncertain linguistic variable; TOPSIS

I. INTRODUCTION

It is well-known that the quality of decision-making affects the organizational operation and performance deeply. In the process of decision-making, how to capture the opinion of decision makers exactly is extremely important. In tradition, MADM methods often solve the problems involving the crisp ratings of alternatives under attributes with crisp weights. However, in real cases the available data used in decision-making problems are often imprecise and vague. For example, the linguistic statement is very often used to evaluate alternatives and/or to indicate the importance of attributes. Linguistic variables are variables whose values (interpretation) are not numbers but words or sentences in a natural or artificial language [1]. The concept of linguistic variable is very useful to treat situations that are too ill-defined or too complicated to be appropriately described in traditional quantitative expressions. Xu(2004) presented that it is unavoidable that experts can only provide uncertain linguistic information due to time pressure and/or lack of sufficient information. Therefore it derived to use linguistic variables to show expression of opinions and preferences [3]. For giving decision-makers the flexibility of evaluation, they can choose two items of linguistic variables by the multiple-choice way with an interval range of uncertain linguistic variables to express their real thinking. For instance, if one decision-maker

wants to give the evaluation that is between “fair” and “satisfied”, then the decision-maker is able to evaluate with such uncertain linguistic variable [fair, satisfied]. Nevertheless, we find it also brings another problem which may produce too large interval range. It includes two kinds of situations. One is too wide range of evaluation from a decision-maker, and the other is too large differences between these evaluations from decision-makers. Therefore, for decision quality, it is necessary to overcome these problems when using such uncertain linguistic variable in evaluation.

Therefore, in this study we develop the UL-TOPSIS (Uncertain Linguistic Technique for Order Preference by Similarity to Ideal Solution), which is used uncertain linguistic variable as input value and applied the theory and spirit of TOPSIS to lead to develop a new operational process. We call the method as Uncertain Linguistic Technique for Order Preference by Similarity to Ideal Solution, UL-TOPSIS, hope to use it to capture the opinions of exports better and make more accurate

II. LITERATURE REVIEW

A. Linguistic Variable

In order to be able to transform the description of natural language into logical description by logic speculation, linguistic variable in fuzzy sets is used to describe the natural language under the domain of specification,. The linguistic variable is based on word or sentence as a variable rather than a number [1]. According to Zadeh (1975) description of linguistic variables, the linguistic terms is referred to the adjective phrase that is used by describing their own feelings of external things in human daily life [1]. For example, the linguistic variable "satisfaction", which can be used in linguistic terms "very dissatisfied ", "not satisfied" and " fair", "satisfied", "very satisfied" and other words to express.

B. Likert Scale

About the questionnaire design of expert opinions for the

criteria, the quantitative method of traditional rating scale is based on using a single value that corresponding to the opinion. That is Likert Scale which is generally familiar with. It is shown in Table I [4].

TABLE I. LIKERT SCALE

Linguistic variable	Very dissatisfied	dissatisfied	general	satisfied	Very satisfied
Corresponding function value	1	2	3	4	5

Likert Scale is used the value of equal difference to converse the answer that is chosen from all options by experts. That is conversed through the correlation between function, as shown in Table I. For different linguistic variables "very satisfied, satisfied, general, satisfactory, very satisfactory " to give the value "1,2,3,4,5," and then to quantify the linguistic variables and proceed follow-up calculation and decision-making.

C. Nine-point Scale

In the decision making methods AHP and ANP that Saaty proposed, it must be evaluate the importance of criteria before decision-making. It is divided into nine levels of importance for experts based on the questionnaire format Saaty designed. Levels of importance are separated into "Equal Importance", "Moderate Importance ", "Strong Importance", "Demonstrated Importance ", "Extreme Importance ", and take intermediate value between each level [6]. So we can let the experts proceed evaluating between two levels .The measure scale is shown in Table II as follow:

TABLE II. MEASURE SCALE

measure scale	Intensity of Definition Importance	Description
1	Equal Importance	Two activities contribute equally to the objective
3	Moderate Importance	Experience and judgment slightly favor one activity over another
5	Strong Importance	Experience and judgment strongly favor one activity over another
7	Demonstrated Importance	An activity is favored very strongly over another; its dominance demonstrated in practice
9	Extreme Importance	The evidence favoring one activity over another is of the highest possible order of affirmation
2, 4, 6, 8	Intermediate Value between two level	Between above of description

source : Saaty, 2006

D. Uncertain Linguistic Variable

In real life, when the experts or policy makers in the assessment criteria, the individual's thinking and cognitive differences have in determining the degree of differentiation,

and implied uncertainty. In order to reflect model of human thinking more closely, we can let the experts use uncertain linguistic directly for expression. The uncertain linguistic representation is an "interval range" of linguistic variables. It is used an "interval range" to replace the option of single linguistic variables, and hoping to more fully express a personal thought and cognition by giving experts flexibility of evaluation, in order to facilitate more effective decision-making activities.

By using the example Xu(2004) mentioned in his study to illustrate that when evaluating criteria, linguistic variable is distinguished between nine terms. S represents a set which include nine linguistic variables:

$$S=\{s_1 = \text{extremely dissatisfied}, s_2 = \text{very dissatisfied}, s_3 = \text{dissatisfied}, s_4 = \text{slightly dissatisfied}, s_5 = \text{fair}, s_6 = \text{slightly satisfied}, s_7 = \text{satisfied}, s_8 = \text{very satisfied}, s_9 = \text{extremely satisfied} \}$$

where s_i represents a possible value for a linguistic variable [3].

However today expert A wants to give the evaluated value which has no clear boundary. He considers that it is fall between "fair" and "satisfaction." Therefore expert A could use $[s_4, s_6]$ such a uncertain linguistic for expression. According to expert B's thinking, the evaluated value he given is between "very dissatisfied" and "slightly satisfied", so he can represent it with $[s_0, s_3]$.

E. TOPSIS

TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) is a multi-attributed evaluation method that have developed by Hwang and Yoon (1981) [7]. It is applied widely in decision-making problems. Followed developing by Yoon (1987) and Hwang and others, the theory have been more complete.

The basic concept of TOPSIS is that the decision-maker based on all evaluated criteria of alternatives to find out the Positive Ideal Solution which is composed of the greatest value of those criteria and the Negative Ideal Solution which is composed of the worst value of those criteria for comparison. The so-called positive ideal solution is to enable the alternatives to be increased to the greatest of effectiveness attribute and reduced to the smallest of cost attribute; The negative ideal solution is to enable the alternatives to be dropped to the smallest effectiveness attribute and to be increased to the greatest of cost attributes.

III. UNCERTAIN LINGUISTIC TECHNIQUE FOR ORDER PREFERENCE BY SIMILARITY TO IDEAL SOLUTION

Uncertain Linguistic Technique for Order Preference by Similarity to Ideal Solution, UL-TOPSIS, which is used uncertain linguistic variable as input value and applied the theory and spirit of TOPSIS. Moreover, it can extend to deal with too much difference of expert opinions, and led to develop a new operational process.

UL-TOPSIS that developed in this study is the assessment of experts in order semantic uncertainty expressed, one expert expressed by the interval range of input values, applied to make expert decisions TOPSIS methods, procedures and contents are described below:

UL-TOPSIS developed in this study is expressed the opinion of experts by the uncertain linguistic, and used the interval range of expert expression as the input value for applying TOPSIS method to make expert decision. The steps and description as follow:

Step1. Establish a multi-criteria decision-making matrix

$$D_e = \begin{matrix} & C_1 & C_2 & \dots & C_n \\ \begin{matrix} A_1 \\ A_2 \\ \vdots \\ A_m \end{matrix} & \begin{bmatrix} x_{11}^e & x_{12}^e & \dots & x_{1n}^e \\ x_{21}^e & x_{22}^e & \dots & x_{2n}^e \\ \dots & \dots & \dots & \dots \\ x_{m1}^e & x_{m2}^e & \dots & x_{mn}^e \end{bmatrix} \end{matrix}, e=1,2,\dots,h \quad (1)$$

$$W_j = [w_1, w_2, \dots, w_n].$$

D_e is the multi-criteria decision-making matrix of the e th expert, $e=1, 2, \dots, h$. A_i indicate the i th alternative, $i=1, 2, \dots, m$; C_j indicate the j th criteria, $j=1, 2, \dots, n$; x_{ij}^e indicate the value that expert e give the j th criteria for i th alternative, $x_{ij}^e = [a_{ij}^e, b_{ij}^e]$; and w_j indicate the importance relative to criteria C_j , $j=1,2,\dots,n$.

Let $b_j - a_j$ be the difference between expert opinions. If $b_j - a_j \geq 5$, we define this as the difference between expert opinions too much.

Step2. To integrate the opinions of each expert who give the same criteria under the same alternative.

$$\begin{aligned} X_{ij} &= [\min_{e=1}^h a_{ij}^e, \max_{e=1}^h b_{ij}^e] \\ &= [a_{ij}, b_{ij}] \end{aligned} \quad (2)$$

Step3. To use the method when the differences between expert opinions are too much

if $b_j - a_j \geq 5$, then do the following steps:

1. Under the same alternative, for the same criteria (j), to calculate the distance of each S_{ij}

$$d(x_{ij}^e, x_{ij}^k) = \sqrt{(b_{ij}^k - b_{ij}^e)^2 + (a_{ij}^k - a_{ij}^e)^2} \quad (3)$$

$$e \neq k, \quad e=1, 2, \dots, m-1$$

$$k=e+1, e+2, \dots, h, \text{ for each } i, j$$

2. To compare the distance $d(S_{ij}, S_{kj})$ and eliminate the outlier

Finding the maximum $d(S_{ij}, S_{kj})$ and eliminate it. We will not to consider the score which the expert given.

3. Then come back to Step 2.

Step4. To normalized the evaluated values of each alternative for the criteria.

$$r_{ij} = \frac{x_{ij}}{9}, \quad i=1, 2, \dots, m; \quad j=1, 2, \dots, n \quad (4)$$

The normalized decision-making matrix could be displayed with $R = [r_{ij}]_{m \times n}$

$$R = \begin{matrix} & C_1 & C_2 & \dots & C_n \\ \begin{matrix} A_1 \\ A_2 \\ \vdots \\ A_m \end{matrix} & \begin{bmatrix} r_{11} & r_{12} & \dots & r_{1n} \\ r_{21} & r_{22} & \dots & r_{2n} \\ \dots & \dots & \dots & \dots \\ r_{m1} & r_{m2} & \dots & r_{mn} \end{bmatrix} \end{matrix}, \quad (5)$$

$$W_j = [w_1, w_2, \dots, w_n].$$

Step5. To make the relative weight of each criteria multiply into the standard matrix to create a normalized weighted matrix

$$V_{ij} = w_j r_{ij}, \quad i=1,2,\dots,m; \quad j=1,2,\dots,n \quad (6)$$

where w_j is the weight of C_j

Step6. To determine the positive ideal solution and negative ideal solution

let $[9,9]$ and $[1,1]$ separately be the positive ideal solution and negative ideal solution of single criteria that not yet be added the weight and normalized.

$$\text{After normalizing, } r^+ = \left[\frac{9}{9}, \frac{9}{9}\right] \quad r^- = \left[\frac{1}{9}, \frac{1}{9}\right]$$

After multiplying the weight value,

$$V^* = w_j r^+; \quad V^- = w_j r^- \quad (7)$$

Then the positive ideal solution A^* of each criteria could be showed as follow:

$$A^* = [V_1^*, V_2^*, \dots, V_j^*, \dots, V_n^*] \quad (8)$$

And the negative ideal solution A^- of each criteria could be showed as follow:

$$A^- = [V_1^-, V_2^-, \dots, V_j^-, \dots, V_n^-] \quad (9)$$

Step7. To calculate the Separation measure

The distance between each alternative and the positive

ideal solution, represents as Separation measure S_i^* :

$$S_i^* = \left\{ \sum_{j=1}^n (V_{ij} - V_j^*)^2 \right\}^{1/2}, i = 1, 2, \dots, m \quad (10)$$

The distance between each alternative and the negative ideal solution, represents as Separation measure S_i^- :

$$S_i^- = \left\{ \sum_{j=1}^n (V_{ij} - V_j^-)^2 \right\}^{1/2}, i = 1, 2, \dots, m \quad (11)$$

Step8. To calculate the relative similarity to the positive ideal solution and negative ideal solution of the compared alternatives, RC_i^* is obtained:

$$RC_i^* = \frac{S_i^-}{S_i^* + S_i^-}, i = 1, 2, \dots, m, 0 \leq RC_i^* \leq 1 \quad (12)$$

Step9. By the relative similarity RC_i^* to the positive ideal solution and negative ideal solution of the compared alternatives, we can know the relative position of compared alternatives to the positive and negative ideal solution, to rank the order of all alternatives. When the value RC_i^* is getting more close to 1, it means the alternative is getting more near the positive ideal solution, and more away from negative ideal solution. Which alternative is the better one. Otherwise, When the value RC_i^* is getting more close to 0, it means that the alternative is getting more near the negative ideal solution, and more away from positive ideal solution. Which alternative is the worse one. Therefore, the greater value RC_i^* of alternative is the priority.

IV. CONCLUSION

The purpose of this study is to provide a practical reference through proposing a new expert decision-making method and applying it to deal with the decision-making problems that practical business management often faced. So we develop the UL-TOPSIS which is used uncertain linguistic variable as input value and applied the theory and spirit of TOPSIS. Moreover, it can extend to deal with too much difference of expert opinions, and led to develop a new operational process. We could use it to capture the opinions of experts better, integrate the opinions of all experts appropriately, and make more accurate decisions for decision makers.

However, there are many multi-criteria decision-making methods, for example: AHP, ANP, etc. In the future, the researchers that interested in it can also use the uncertain linguistic variables and the concepts of dealing with too large differences in this study to apply in the multiple-criteria decision making method. And use it to develop the more diversified approach of decision-making and operational processes to provide a reference that could handle the more complex problems of management decision-making in practice.

REFERENCES

- [1] L. A. Zadeh, "The concept of a linguistic variable and its application to approximate reasoning I, II, III," *Information Science*, 8, 199-251, 301-357, 9, pp. 43-80, 1975.
- [2] R. E. Bellman and L. A. Zadeh, "Decision-making in a fuzzy environment," *Management Science*, 17(4), pp. 141-146, 1970.
- [3] Z. Xu, "Uncertain linguistic aggregation operators based approach to multiple attribute group decision making under uncertain linguistic environment," *Information Sciences*, 168, pp. 171-184, 2004.
- [4] R. Likert, "A Technique for the Measurement of Attitudes," *Archives of Psychology*, 140, pp. 1-55, 1932.
- [5] T. L. Saaty, "The analytic hierarchy process," McGraw-Hill, New York, 1980.
- [6] T. L. Saaty and L. G. Vargas, "Decision Making With the Analytic Network Process: Economic, Political, Social And Technological Applications With Benefits, Opportunities, Costs and Risks," Springer Verlag, 2006.
- [7] Hwang, C.L., & Yoon, K., "Multiple Attributes Decision Making Methods and Applications," Springer, Berlin Heidelberg, 1981.