Linguistic Decision Analysis Based Technology Project Assessment

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ABSTRACT: *The problem considered in this paper is that of selecting, from a set of proposals or a subset of projects to be undertaken. Technology project assessment is influenced by a large number of factors, and many times it is hard to measure them in numbers or an objectively way. This paper addresses this by presenting a method for identifying and assessing key project characteristics, which are crucial for a technology project's assessment. Fistly, this paper builds a new set of indicators of technology project assessment after analysing the process of it. Secondly, this paper introduces two aggregation operators in the technology project to deal with two situations of technology project assessment respectively, including linguistic and subjective information and pair comparison of preference relation. The methods consist of a number of well-defined steps, which are described in detail. Finally, examples show that the proposed methods with the linguistic decision analysis are useful and provide an understanding way for the decision maker.*

Categories and Subject Descriptors
K.6.1[Project and people management] K.6 .4 [System management]

General Terms
Project assessment, Lingusitic decision analysis

Keywords: Technology Project management, Project assessment, Linguistic decision analysis, Aggregation operator

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1. Introduction

Traditional technology assessment is almost dealt with real numbers. Ref.[1] summarizes several methods. But in the process of the assessment of technology project, it may be difficult or impossible to develop and use objective quantitative measures for many of these project characteristics and success indicators. Even when quantitative measures exist, they may not be usable for a variety of reasons such as inconsistent measurement and lack of priorities in selecting measures [2]. This can lead to not measuring important project characteristics or success indicators at all.

It is often quicker and easier to collect subjective measures during or after project completion. For example, when attempting to qualify phenomena related to reputation of a corporation, we are often led to using words in natural language instead of numerical values. As was pointed out in, this may arise for different reasons. There are some situations in which the information may be unquantifiable due to its nature, and thus, it may be stated only in linguistic terms (e.g., when evaluating the "comfort" or "design" of a car, terms like "good", "medium", "bad" can be used). In other cases, precise quantitative information may not be stated because either it is unavailable or the cost of its computation is too high, so an "approximate value" may be tolerated [3] (e.g., when evaluating the speed of a car, linguistic terms like "fast", "very fast", "slow" may be used instead of numerical values)[1].

In practical project assessment, variables are not numbers but words or sentences in a natural or artificial language. Sometimes the information cannot be assessed precisely in a quantitative form but may be in a qualitative one. And in some situations, the input arguments take the form of uncertain linguistic variables rather than numerical ones because of time pressure, lack of knowledge, and the decision makers' limited attention and information processing capabilities [4] or some other reasons. Therefore, it is necessary to pay attention to this issue.

Linguistic decision analysis is based on the use of the linguistic approach and it is applied for solving decision-making problems under linguistic information. Its application in the development of the theory and methods in decision analysis is very beneficial because it introduces a more flexible framework which allows us to represent the information in a more direct and adequate way when we are unable to express it precisely [3]. In this way, the burden of quantifying a qualitative concept is eliminated.

Making decisions with linguistic information is a usual task faced by many decision makers [2,3,4,5,13], and thus, the use of a linguistic and subjective approach is necessary. Many approaches have been proposed for aggregating information up to now [2,3,4,5,6,15]. An ordinal linguistic computational model, which makes direct computations on labels, using the ordinal structure of the linguistic term sets has been developed in reference [7]. An approximate computational model, based on the extension principle, to make computations over the linguistic variables has been developed in Ref. [8]. Herrera and Martinez have developed a fuzzy linguistic representation model, which represents the linguistic information with a pair of values called 2-tuple, composed by a linguistic term and a number [9], and Wang developed it [10]. Xu [11] has developed a direct approach to decision making with linguistic preference relations. All of these approaches, however, do not consider about the indicators.

But in fact, it is important to decide what to evaluate when judging the success of technology project. The technology project indicators believed to influence the success variables are identified, and suitable assessment methods are determined. The indicators are measured through variables. Technology project indicators provide a view of the status or quality of the project, and they can be estimated prior to starting the project. An indicator is subjective, if a subjective measure is used to measure the corresponding variables.

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It also should be noted that although linguistic and subject is important, but in some situation people is inclined to compare reference relation of technology projects pair to pair, especially the number of the projects is not so much. In [3, 22], Herrera develop methods about this and a fuzzy preference relation is computed from the collective performance values using a ranking method of pairs of fuzzy sets in the setting of Possibility Theory, applied to the fuzzy sets on the basic linguistic term set. Then, a choice degree is used to reach a solution set of alternatives. But few is considered about this problem in technology projects. As in the assessment of technology project, the indicators influence the whole assessment greatly and have their own characters, so technology project assessment is different from that of other projects.

To solve the aforementioned problems in technology project assessment, this paper builds a new set of indicators and introduces two aggregation operators in the technology project to deal with two situations of technology project assessment respectively, including linguistic and subjective information and pair comparison of preference relation.

The following sections are: In section II, we built a new indicator system of technology project assessment, including process of technology project assessment in A, and propose a new indicators system in B. Section III presents linguistic and subjective scale based on the ordered structure of the linguistic term set. Section IV presents linguistic UEWOA aggregation operator, including introducing uncertain linguistic variables and some operational laws in A and presenting linguistic approach step by step in B. Section V presents linguistic LOWA aggregation operator. Section VI presents the examples and analysis. Finally, we give our conclusion.

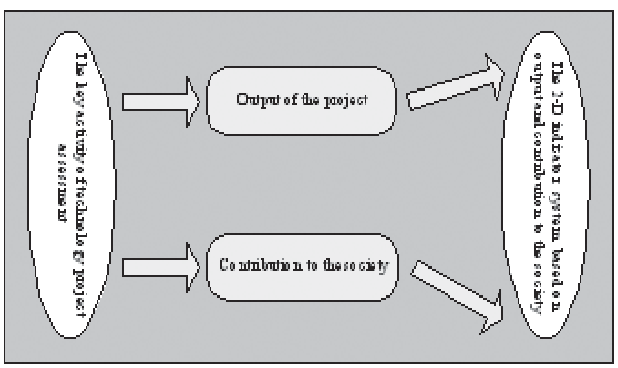

Figure 1. 2-dimension project evaluation indicator system analysis

2. Indicator system of technology project assessment

Before the analysis, important aspects to study in the analysis should be identified. For our purposes, it must be decided which project aspects should be assessed. It is essential to determine what to measure quantitatively and what to evaluate subjectively. This section is to determine the indicators and how to define the indicators.

2.1 Process of technology project assessment

The technology project has been researched by many documents [16,17,18,19]. Technology projects are important to the development of a country. Technology project assessment is different from that of other projects. It should not be only concentrated the output but also contribution to the society. We consider the key activity of project evaluation as two parallel process: output of the project and contribution to the society (as shown in Fig. 1). According to it, we make a 2-dimension indicator system based on output and contribution to the society.

2.2 Selection of indicators

The indicators are measured through variables. Technology project indicators provide a view of the status or quality of the project, and they can be estimated prior to starting the project. An example of a project factor may be project management. This factor may include project characteristics such as the quality of the project plan and experience of the project manager. The experience of the project manager may be studied through different variables, for example, number of times as project leader or through a survey among participants in previous projects [2]. The first variable may be measured through calculating an absolute number, but it is also possible that it is judged that it is better to capture the experience on a seven-point scale, since the differences exit between having been project leader.

Technology project evaluations are influenced by many project variables, since it is crucial for evaluation of technology projects. The next question is which Technology project variables drive specific success indicators in the indictor system.

As mentioned in section II A, we make 2-dimension indicator system based on output and contribution to the society, the two parallel process of technology project evaluation. As shown in Fig.2, the indicator system includes four parts: technique evaluation, market evaluation, input-output evaluation and corporation-situation evaluation. Every part includes two subparts: one is related to output of the project (denoted by real line), and the other is related to the contribution to the society (denoted by dashed line). Technique evaluation

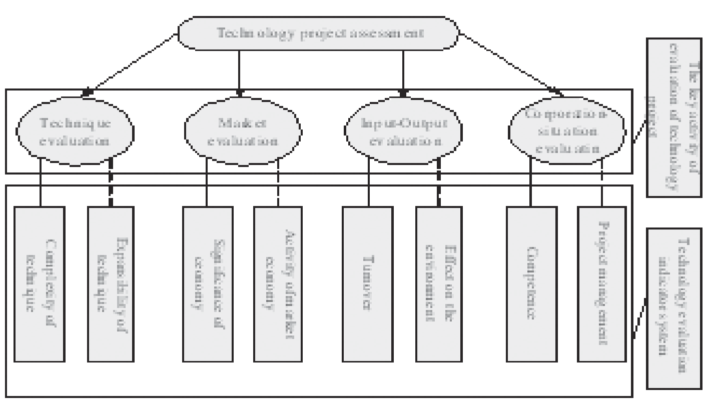

Figure 2. The structure of 2-dimension technology

includes complexity of technique and expansibility of technique; market evaluation includes significance of economy and activity of market circulation; Input-output evaluation includes turnover and effect on the environment; and corporation-situation evaluation includes competence and project management. The brief description is listed in Tab.2, in section VI.

The indicators are measured through variables. Technology project indicators provide a view of the status or quality of the project, and they can be estimated prior to start the project.

3. Linguistic and subjective scale based on the ordered structure of the linguistic term set

An indicator is subjective, if a subjective measure is used to measure the corresponding variables. An alternative possibility, which does not use fuzzy sets, introduces the semantic from the structure defined over the linguistic term set [3]. In particular, this happens when the users provide their assessments by using an ordered linguistic term set [14, 15, 16]. Under this semantic approach, depending on the distribution of the linguistic terms on a scale ([0, 1]), there are two possibilities for defining the semantic of the linguistic term set: symmetrically distributed terms and non-symmetrically distributed terms.

Assuming symmetrically distributed terms assumes ordered linguistic term sets which are distributed on a scale, as was mentioned, with an odd cardinal, and the mid term representing an assessment of “approximately 0.5” and with the rest of the terms being placed symmetrically around it. Then, the semantic of the linguistic term set established from the ordered structure of the term set by considering that each linguistic term for the pair (s_i; s_{T-i}) is equally informative [16]. This proposal may be explicitly defined by assigning a subdomain of the reference domain [0, 1] to each linguistic term [14, 15, 16], as shown in Fig. 3. For example, S = {s0.0 = none, s0.1 = very low, s0.2 = low, s0.3 = medium, s0.4 = high, s0.5 = very high, s0.6 = perfect} is symmetrically distributed ordered set of linguistic terms.

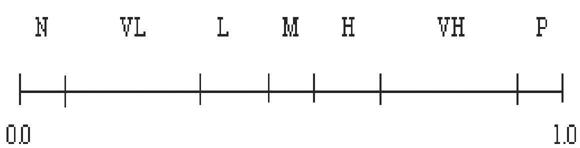

Figure 3. A symmetrically distributed ordered set of linguistic terms

Assuming non-symmetrically distributed terms. It assumes that a subdomain of the reference domain may be more informative than the rest of the domain [17], and it is not discussed in this paper.

It should be noted that even if a variable may be measured objectively, as for example turnover, it may be chosen to simply determine how good the turnover is on a grade scale. For measuring subjective variables various rating schemes exist, for example, ordinal scales [14]. The meaning of the different values on the scale should be determined and these should provide a good differentiation between projects.

4. Linguistic UEWOA aggregation operator

In this section, the problem we considered is how to aggregate preference with subjective and linguistic information for technology project assessment.

4.1 Uncertain linguistic variables and some operational laws

To preserve all the given information, we extend the discrete multiplicative linguistic label S set to a continuous multiplicative linguistic label set $\bar{S} = \{s_\alpha \mid \alpha \in [1/q, q]\}$, where $q (q > t)$ is a sufficiently large positive integer. If, $s_\alpha \in S$ then we call S_α the original multiplicative linguistic label; otherwise, we call the virtual multiplicative linguistic label [6]. In general, the decision maker uses the original multiplicative linguistic labels to evaluate alternatives, and the virtual multiplicative linguistic labels can only appear in operations. Let, $\tilde{s} = [s_\alpha, s_\beta]$ where $s_\alpha, s_\beta \in \bar{S}$, s_α and s_β are the lower and upper limits, respectively. We then call $\tilde{s}$ the uncertain multiplicative linguistic variable. Let $\tilde{S}$ be the set of all the uncertain multiplicative linguistic variables. Consider any three uncertain linguistic variables s_λ, s_{λ_1}, s_{λ_2}, and any three uncertain linguistic variables $\tilde{s} = [s_\alpha, s_\beta]$, $\tilde{s}_1 = [s_{\alpha_1}, s_{\beta_1}]$ $\tilde{s}_2 = [s_{\alpha_2}, s_{\beta_2}]$, we define their operational laws as the following:

(1) $\tilde{s}_1 \oplus \tilde{s}_2 = [s_{\alpha_1}, s_{\beta_1}] \oplus [s_{\alpha_2}, s_{\beta_2}] = [s_{\alpha_1} \oplus s_{\alpha_2}, s_{\beta_1} \oplus s_{\beta_2}]$

$= [s_{\alpha_1 + \alpha_2}, s_{\beta_1 + \beta_2}]$

(2) $\tilde{s}_1 \otimes \tilde{s}_2 = [s_{\alpha_1}, s_{\beta_1}] \otimes [s_{\alpha_2}, s_{\beta_2}] = [s_{\alpha_1} \otimes s_{\alpha_2}, s_{\beta_1} \otimes s_{\beta}]$

$= [s_{\alpha_1 \alpha_2}, s_{\beta_1 \beta_2}]$

(3) $s_\lambda \otimes \tilde{s} = s_\lambda \otimes [s_\alpha, s_\beta] = [s_\lambda \otimes s_\alpha, s_\lambda \otimes s_\beta] = s_{\lambda\alpha}, s_{\lambda\beta}$

(4) $\tilde{s}_1 \oplus \tilde{s}_2 = \tilde{s}_2 \oplus \tilde{s}_1$

(5) $\tilde{s} \otimes (\tilde{s}_1 \oplus \tilde{s}_2) = (\tilde{s} \otimes \tilde{s}_1) \oplus (\tilde{s} \otimes \tilde{s}_2)$

(6) $\tilde{s}_\lambda \otimes (\tilde{s}_1 \oplus \tilde{s}_2) = (\tilde{s}_\lambda \otimes \tilde{s}_1) \oplus (\tilde{s}_\lambda \otimes \tilde{s})$

(7) $(\tilde{s}_1 \oplus \tilde{s}_2) \otimes \tilde{s} = (\tilde{s}_1 \otimes \tilde{s}) \oplus (\tilde{s}_\lambda \otimes \tilde{s})$

(8) $(\tilde{s}_{\lambda_1} \oplus \tilde{s}_{\lambda_2}) \otimes \tilde{s} = (\tilde{s}_{\lambda_1} \otimes \tilde{s}) \oplus (\tilde{s}_{\lambda_2} \otimes \tilde{s})$

Definition 1 Let $s_1 = [\tilde{s}_{\alpha_1}, s_{\beta_1}]$ and $\tilde{s}_2 = [s_{\alpha_2}, s_{\beta_2}]$ be two uncertain multiplicative linguistic variables, and let $len(\tilde{s}_1) = \beta_1 - \alpha_1$ and $len(\tilde{s}_2) = \beta_2 - \alpha_2$, then the degree of possibility of defined as:

$$p(\tilde{s}_1 \ge \tilde{s}_2) = \max\left\{1 - \max\left(\frac{\beta_2 - \alpha_1}{len(\tilde{s}_1) + len(\tilde{s}_2)}\right), 0\right\} \qquad (1)$$

Similarly, the degree of possibility of $\tilde{s}_2 \ge \tilde{s}_1$ is defined as:

$$p(\tilde{s}_2 \ge \tilde{s}_1) = \max\left\{1 - \max\left(\frac{\beta_1 - \alpha_2}{len(\tilde{s}_1) + len(\tilde{s}_2)}\right), 0\right\} \qquad (2)$$

The above possibilities compose a complementary matrix $p = (p_{ij})_{n \times n}$, where $p_{ij} = \tilde{p}(s_i \ge \tilde{s}_j)$, which is normalized as vi:

$$v_i = \frac{1}{n(n-1)}\left(\sum_{j=1}^{n} p_{ij} + \frac{n}{2} - 1\right), i \in N \qquad (3)$$

4.2 Linguistic approach

Definition 2 An uncertain linguistic UEOWA operator is defined as following:

$$UEWO\tilde{A}(\tilde{s}_n)=w_1\tilde{s}_{\beta 1} \oplus w_2\tilde{s}_{\beta 2} \ldots \oplus w_1\tilde{s}_{\beta 1}$$

Where $w=(w_1,w_2,..w_n)^T$ is a weighting vector, such that $w_j \in [0,1]$, $\sum_{j=1}^{n} w_j=1$, s_j is the s_i value of the pair (u_j,s_j) having the j th largest u_j.

In the following, we shall develop UEOWA in technology project evaluation. For the multiple attribute decision-making problems, in which the attribute weights take the form of linguistic variables and the preference values take the form of uncertain linguistic variables, we shall develop a linguistic approach based on the UEOWA operator as follows [15]:

Step 1: Let $X = \{x_1,x_2, \ldots,x_n\}$ be a discrete set of alternatives, $U = \{u_1, u_2, \ldots ,u_m\}$ be the set of attributes, and $S_\lambda = \{S_{\lambda 1}, S_{\lambda 2}, \ldots,S_{\lambda m}\}$ be the linguistic weight vector of the attributes u_i (i = 1, 2 , …,m)

Step 2: To rank these collective overall preference values EOWA, we first compare each u_j (j = 1, 2, …, n)by using Eq.(1). For simplicity, we let $P_{ij} = (p_{ij})_{nxn}$ where $p_{ij} =p(u_i\, u_j)$ $0,p_{ij} +p_{ji} =1,\ p_{ii}=1/2,\ i,j = 1,2,...,n.\ p(u_i>u_j)>0,p_{ij} +p_{ji} =1,p_{ii}=1/2,\ i,j =1,2,...,n.$. According to Eq.(2), we get the ordered vector $v_i = (v_1, v_2, \ldots, v_n)$

Step 3: In accordance with the collective overall preference values, $UEWOA(s_n)=w_1\tilde{s}_{\beta 1} \oplus w_2\tilde{s}_{\beta 2}\ldots \oplus w_1\tilde{s}_{\beta 1}$ and we can get z_i (w), (i = 1, 2 , …,n).

Step 4: Repeat step 2 and get the vector v. According to v in a descending way, we can rank all the alternatives.

5. Linguistic lowa aggregation operator

As mentioned in section I, sometimes people is inclined to compare technology project pair to pair comparison, especially the number of the projects is not so much. So in this section, we focus on Linguistic preference relation in technology project assessment. In this case, for a criterion a linguistic preference relation is supplied over the set of alternatives $V_k =v_{ij}^k$, reflecting each element of the relation v_{ij}^k, the linguistic degree to which an alternative x_i is preferred to another x_j [20,21], and the suitable metrics are determined.

5.1 Some operational laws of LOWA

In [3, 22], F.Herrera et al. provides the definition of the LOWA (the Linguistic Ordered Weighted Averaging) aggregation operator.

Let $A = \{a_1, \ldots ,a_m\}$ be a set of labels to be aggregated, then the LOWA operator, $\varnothing$,is defined as

$$(a_1, \ldots, a_m) = W.B^T =C^m \{w_k, b_k, k =1, \ldots, m\}$$

$$= w_1 \odot b_1 \oplus (1-w_1) \odot C^{m-1}\{ \beta_h, b_h, h =2, \ldots , m\}$$

where $W = [w_1, \ldots , w_m]$, is a weighting vector, such that:

(1) $w_i \in [0,1]$

(2) $\sum w_i = 1, \beta_h = w_h / \sum_2^m w_k,\ h = 2, \ldots , m,$

And $B = \{b_1, \ldots ,b_m\}$ is a vector associated to A, such that $B = a_{\sigma(1)},\ldots,a_{\sigma(n)}$, where $a_{\sigma(j)} \le a_{\sigma(i)}\ \forall\ i \le j$, with σ being a permutation over the set of labels $A.C^m$ is the convex combination operator of m labels, $\odot$ is the general product of a label by a positive real number and $\oplus$ is the general addition of labels defined in [22]. If m = 2, then C^2 is defined as

$$C^2\{w_i,b_i,i=1,2\}=w_1\odot s_j \oplus (1-w_1)\odot s_i=s_k,s_j,s_i \in S,(j \ge i)$$

such that $k=\mathbf{min}\{T,i+round(w_1\cdot(j-i))\}$,where "round" is the , usual round operation, and $b_1=s_j,b_2=s_i$. If w_j=1 and w_i=0 with $i \neq j\ \forall$, then the convex combination is defined as $C^m\{w_i,b_i,i=1,...,m\}=bj.$

5.2 Obtaining of the weighting vector

Yager proposed two ways on how to calculate the weighting vector of LOWA operator W [23]. To use the concept of fuzzy majority by means of the weighting vector in the aggregations of the LOWA operator, we consider trying to give some semantics or meaning to the weights.

In part C, we will show the linguistic quantifier in detail. We shall briefly introduce the concept of the fuzzy linguistic quantifier. Human often express ideas in its quantifiers, e.g. all, there exits, average, less than α, most , few, which will be represented in this section, part C. Classic logic is restricted only to the use of two quantifiers, there exists and for all. Zadeh, using Fuzzy logic, introduced the concept of linguistic quantifier to represent the large number of possible quantifiers. Zadeh suggested that the semantic of a linguistic quantifier may be captured by using fuzzy subsets for its representation. He distinguished between two types of linguistic quantifiers, absolute and proportional. These absolute linguistic quantifiers, such as "about 2" or "few", are closely related to the concept of the count or number of elements.

Fuzzy majority is a soft majority concept, which is manipulated via a fuzzy logic-based calculus of linguistically quantified propositions. Kacpryzk specified the fuzzy majority rule by means of a linguistic quantifier to derive various solutions concepts for group decision-making problems in a numerical setting [24]. We shall work in a similar way, but in the field of quantifier guided aggregations. Below, we will show the linguistic quantifier in detail.

A key step of this aggregation is the re-ordering of alternatives in a descending order so that the weight w_j is associated with the ordered position of the alternatives.

5.3 Linguistic quantifier

In [26], David Ben-Arieh presents the concept of linguistic quantifiers and presents a collection of quantifiers with their associated weight functions. According to Zadeh, linguistic quantifiers, Q(r), can be viewed as linguistic probability, which determines the degree that the concept Q has been satisfied by r. In exploring this concept, Zadeh also proposed the concepts of absolute and relative or proportional quantifiers. The absolute quantifier represents the linguistic terms which related to an absolute count such as 'At least 5' and 'More than 10'. The relative or proportional quantifier represents the term containing the proportion r where r belongs to the unit interval. Examples of relative quantifiers are 'at least 0.5' and 'more than 0.3', as well as 'many' and 'few'. Yager (1991) categorized the relative quantifiers into three categories;

1. Regular monotonically non-decreasing. As mentioned, the quantifier Q(r) can be perceived as the degree that the concept Q has been satisfied by r. In this type of quantifiers, as more criteria are satisfied, the higher the value of the quantifier. Examples for this type of quantifier are 'Most', 'All', 'More than α ', 'There exists', and 'At least α'. This type of quantifier has the following properties

(1) $Q(0)$;

(2) $Q(1)$;

(3) If $r1 > r2$ then $Q(r_1) \geq Q(r_2)$.

3.Regular unimodal. These quantifiers are used to express linguistic terms such as 'About ' α or 'Close to α ' which implies that the maximum satisfaction is achieved when exactly a is satisfied. This quantifier is characterized by:

(1) $Q(0) = Q(1) = 0$;

(2) $Q(r) = 1 \quad for \ a \leq r \leq b$;

(3) $r_2 \leq r_1 \leq a \ then \ Q(r_1) \geq Q(r_2)$

(4) $r2 \geq r1 \geq a \ then \ Q(r2) \geq Q(r1)$

5.4 Weights calculation

Since the LOWA aggregation method requires a set of weights wi, these weight have a profound effect on the solution (the ranking of the alternatives in order of preference). One approach for generating the weights has been proposed in Yager (1993, 1996) for the regular monotonically non-decreasing quantifiers.

Using this approach the weights are calculated using

$$w_i = Q\left(\frac{i}{n}\right) - Q\left(\frac{i-1}{n}\right), \ i=1,\ldots,n \qquad (4)$$

Calculating the weights for the regular monotonically non-increasing quantifiers is base on the fact that these quantifiers are the antonyms to the regular monotonically non-decreasing quantifiers (Yager, 1993). Thus these weights are defined as:

$$w_i = Q\left(\frac{i-1}{n}\right) - Q\left(\frac{i}{n}\right) \qquad (5)$$

The generated weights have the following properties

(1) $\sum w_i = 1$;

(2) $w_i = [\mathbf{0,1}]$

This research uses both the regular monotonically non-decreasing and non-increasing quantifiers. The study explores seven families of such quantifiers as follows.

1. 'All'

This quantifiers is also defined as the logical 'AND' quantifier and can be represented as (Kacprzyk & Yager, 1984; Yager, 1983, 1988, 1993, 1996):

$$Q\left(\frac{i}{n}\right) = \begin{cases} 0 & for \ \frac{i}{n} < \mathbf{1} \\ 1 & for \ \frac{i}{n} = \mathbf{1} \end{cases}$$

This representation shows that the satisfaction is a step function achieved only when all the criteria are included.
From Eq. (4) the weights derived are:

$$w_i = \begin{cases} & for \ i < n \\ & for \ i = n \end{cases}$$

2. 'There exists'

This quantifier is equivalent to the term 'At least one' and can be represented as

$$Q\left(\frac{i}{n}\right) = \begin{cases} 0 & for \ \frac{i}{n} = 1 \\ 1 & for \ \frac{i}{n} < 1 \end{cases} \qquad (7)$$

The weights derived are:

$$w_i = \begin{cases} 1 & for \ i = 1 \\ 0 & for \ i \neq 1 \end{cases}$$

This quantifier exhibits complete satisfaction when one criterion is included.
3. 'Average'

From Yager (1988, 1993), the term 'Average' which is the regular averaging function can be represented as

$$Q\left(\frac{i}{n}\right) = \frac{i}{n} \qquad (8)$$

and

$$w_i = \frac{1}{n} \quad for \ all \ i.$$

4. 'Less than α '
The level of satisfaction is calculated as shown in Eq. (10).

$$Q_{less \ than \ \alpha}\left(\frac{i}{n}\right) = \begin{cases} 1 - \frac{i}{n\alpha} & for \quad 0 < \frac{i}{n} \leq \alpha \\ 1 & for \quad \alpha < \frac{i}{n} \leq 1 \end{cases} \qquad (10)$$

This is regular monotonically non-increasing quantifier, thus the weights are calculated by Eq.(7).
5. 'More than α '

From Wang and Lin (2003), the term 'More than a' can be represented as

$$Q_{more \ than \ \alpha}\left(\frac{i}{n}\right) = \begin{cases} 0 & for \quad 0 < \frac{i}{n} \leq \alpha \\ \frac{\frac{i}{n} - \alpha}{1 - \alpha} & for \quad \alpha < \frac{i}{n} \leq 1 \end{cases} \qquad (11)$$

$$Q_{most}\left(\frac{i}{n}\right) = \begin{cases} 1 & for \quad 0 < \frac{i}{n} \leq 0.3 \\ \frac{\frac{i}{n} - 0.3}{0.8 - 0.3} & for \quad 0.2 < \frac{i}{n} < 0.7 \\ 0 & for \quad \frac{i}{n} \geq 0.7 \end{cases} \qquad (12)$$

In this case also the weights are calculated by Eq. (4).
Weights are calculated by Eq. (4).
6. 'Most'
In [27], Smith and Wang and Lin in [28] present that the term 'Most' can be represented as

$$Q_{most}\left(\frac{i}{n}\right) = \begin{cases} 1 & for \quad 0 < \frac{i}{n} \leq 0.3 \\ \frac{\frac{i}{n} - 0.3}{0.8 - 0.3} & for \quad 0.2 < \frac{i}{n} < 0.7 \\ 0 & for \quad \frac{i}{n} \geq 0.7 \end{cases}$$

In this case also the weights are calculated by Eq. (4).

7. 'Few'

This quantifier is a regular monotonically non-increasing quantifier so the weights are calculated by Eq. (5).

All these weights are used in the OWA process to generate the overall score of each alternative. This is done using the ordered scores the criteria of each alternative.

$$Q_{few}\left(\frac{i}{n}\right)=\begin{cases} 1 & for \quad 0<\frac{i}{n}\leq 0.2 \\ \frac{0.7-\frac{i}{n}}{0.7-0.2} & for \quad 0.2<\frac{i}{n}<0.7 \\ 0 & for \quad \frac{i}{n}\geq 0.7 \end{cases} \tag{13}$$

5.5 The choice of the best alternatives

Assuming a linguistic framework, in an MCDM problem we have linguistic performance values $\{V_1,\ldots,V_m\}$ about a set of alternatives $X=\{x1, \ldots, xn\}$ provided according to a group of criteria $\{P_1,\ldots, P_m\}$. Then, the goal consists of finding the best alternatives from the linguistic performance values. This task is achieved by means of a choice process between the alternatives [25]. As is known, basically two approaches may be considered to carry out a choice process. A direct approach $\{V_1,\ldots, V_m\} \rightarrow$ the best alternatives according to which, on the basis of the individual preferences, a solution with the best alternatives is derived, and an indirect approach $\{V_1,\ldots, V_m\} \rightarrow V^c \rightarrow$ the best alternatives providing the best alternatives on the basis of a collective preference, V^c, which is a preference of the group of criteria as a whole. Here, we assume an indirect approach.

As was aforementioned earlier, the proposed choice process is carried out in two phases: (1) aggregation phase of linguistic information and (2) the exploitation phase for the aggregated linguistic information.

6. Exmples and analysis

In this section, the two examples show the two problems in technology project assessment respectively, including linguistic and subjective information and pair comparison of preference relation. We introduce the two aggregation operators mentioned above to solve them.

6.1 Example I of technology project which have no comparison

Let us suppose that there are some technology projects. A government wants to select a best alternative to invest, and experts need to give a suggestion to the government. We assume that all project and success measures have been formulated so that a higher value on a subjective variable is better. Hence, it is expected that all project variables have a positive correlation with the variables

	u_1	u_2	u_3	u_4
	$[s_3, s_4]$	$[s_0, s_2]$	$[s_1, s_3]$	$[s_2, s_3]$
x_2	$[s_5, s_6]$	$[s_3, s_4]$	$[s_1, s_3]$	$[s_0, s_2]$
x_3	$[s_1, s_2]$	$[s_4, s_5]$	$[s_1, s_3]$	$[s_0, s_1]$
x_4	$[s_0, s_1]$	$[s_0, s_1]$	$[s_2, s_3]$	$[s_0, s_1]$
	u_5	u_6	u_7	u_8
x_1	$[s_2, s_4]$	$[s_1, s_2]$	$[s_2, s_3]$	$[s_0, s_1]$
x_2	$[s_2, s_4]$	$[s_3, s_5]$	$[s_1, s_2]$	$[s_4, s_6]$
x_3	$[s_0, s_1]$	$[s_0, s_1]$	$[s_1, s_3]$	$[s_0, s_1]$
x_4	$[s_1, s_2]$	$[s_2, s_4]$	$[s_0, s_1]$	$[s_0, s_2]$

Table 1. Decision matrix A

For example, one may expect that higher competence in a project will make it more likely to be successful, but on the other hand the most competent personnel may be assigned to the most difficult and demanding projects. To address issues like this, it is useful to screen the data, i.e. project variables that do not have a positive correlation with the variable are removed from the analysis.

The four possible alternatives x_i (i =1, 2, 3, 4) are evaluated using the linguistic term setÿand u_j (j = 1, 2, 3, 4, 5, 6, 7, 8) are indicators of the technology projects, as shown in Tab.1. In

Indicators	Brief description	linguistic evaluation
Complexity of technique	Problem complexity	0: many very difficult subsystems 6: no difficult subsystems
Expansibility of technique	The degree that the technique can be developed	0: only used for this particular project 6: can be used for most project
Significance of economy	Popularity with the market	0: not accepted by market 6: popular with market
Activity of market circulation	Potential in the market in a long term	0: not hopeful in the future market at all 6: hopeful in the future market
Turnover	Staff turnover	0: $\leq$ 1%6: $\geq$ 20%
Effect on the environment	Effect on environment	0: destroy environment badly 6: no bad effect on environment at all
Competence	Competence of the project personnel	0: all newly employed6: all experienced
Project management	Performance of management	0: Bad, no control or motivation

Table 2. Description of data

general meaning, $s_0 \sim s_6$ are defined like this: S = {s_0 = extremely poor, s_1 = very poor, s_2 = poor, s_3 = medium, s_4 = good, s_5 = very good, s_6 = extremely good}. While in this particular problem, Tab.2 gives the brief description of the indicators and the particular meaning of s_0 to s_6 and u_j is defined as the following:

(1) u_1 is complexity of technique
(2) u_2 is expansibility of technique
(3) u_3 is significance of economy
(4) u_4 is activity of market circulation
(5) u_5 is turnover
(6) u_6 is effect on the environment
(7) u_7 is competence
(8) u_8 is project management

step 1:

step 1.1: To rank these overall preference values, u_j ($j = 1,2,3,4,5,6,7,8$) we first compare each u_j with all the other u_j by using equation (1), and then develop four complementary matrix:

$$P^{(1)} = \begin{bmatrix} 0.5 & 1 & 1 & 1 & 0.667 & 1 & 1 & 1 \\ 0 & 0.5 & 0.25 & 0 & 0 & 0.333 & 0 & 0.667 \\ 0 & 0.75 & 0.5 & 0.75 & 0.25 & 0.667 & 0.333 & 1 \\ 0 & 1 & 0.25 & 0.5 & 0.333 & 1 & 0.5 & 1 \\ 0.333 & 1 & 0.75 & 0.667 & 0.5 & 1 & 0.667 & 1 \\ 0 & 0.667 & 0.333 & 0 & 0 & 0.5 & 0 & 1 \\ 0 & 1 & 0.667 & 0.5 & 0.333 & 1 & 0.5 & 1 \\ 0 & 0.333 & 0 & 0 & 0 & 0 & 0 & 0.5 \end{bmatrix}$$

$$P^{(2)} = \begin{bmatrix} 0.5 & 1 & 1 & 1 & 1 & 1 & 1 & 0.667 \\ 0 & 0.5 & 1 & 1 & 0.667 & 0.333 & 1 & 0 \\ 0 & 0 & 0.5 & 0.75 & 0.25 & 0 & 0.667 & 0 \\ 0 & 0 & 0.25 & 0.5 & 0 & 0 & 0.333 & 0 \\ 0 & 0.333 & 0.75 & 1 & 0.5 & 0.25 & 1 & 0 \\ 0 & 0.667 & 1 & 1 & 0.75 & 0.5 & 1 & 0.25 \\ 0 & 0 & 0.333 & 0.667 & 0 & 0 & 0.5 & 0 \\ 0.333 & 1 & 1 & 1 & 1 & 0.75 & 1 & 0.5 \end{bmatrix}$$

$$P^{(3)} = \begin{bmatrix} 0.5 & 0 & 0.333 & 1 & 1 & 1 & 0.333 & 1 \\ 1 & 0.5 & 1 & 1 & 1 & 1 & 1 & 1 \\ 0.667 & 0 & 0.5 & 1 & 1 & 1 & 0.5 & 1 \\ 0 & 0 & 0 & 0.5 & 0.5 & 0.5 & 0 & 0.5 \\ 0 & 0 & 0 & 0.5 & 0.5 & 0.5 & 0 & 0.5 \\ 0 & 0 & 0 & 0.5 & 0.5 & 0.5 & 0 & 0.5 \\ 0.667 & 0 & 0.5 & 1 & 1 & 1 & 0.5 & 1 \\ 0 & 0 & 0 & 0.5 & 0.5 & 0.5 & 0 & 0.5 \end{bmatrix}$$

$$P^{(4)} = \begin{bmatrix} 0.5 & 0.5 & 0 & 0.5 & 0 & 0 & 0.5 & 0.333 \\ 0.5 & 0.5 & 0 & 0.5 & 0 & 0 & 0.5 & 0.333 \\ 1 & 1 & 0.5 & 1 & 1 & 0.333 & 1 & 1 \\ 0.5 & 0.5 & 0 & 0.5 & 0 & 0 & 0.5 & 0.333 \\ 0 & 1 & 0 & 1 & 0.5 & 0 & 1 & 0.667 \\ 0 & 1 & 0.667 & 1 & 1 & 0.5 & 1 & 1 \\ 0.5 & 0.5 & 0 & 0.5 & 0 & 0 & 0.5 & 0.333 \\ 0.667 & 0.667 & 0 & 0.667 & 0.333 & 0 & 0.667 & 0.5 \end{bmatrix}$$

step 1.2 :

In each complementary matrix, we calculate the corresponding vi (i = 1, 2, 3, 4) using equation (3), and we can get the vector of vi (i = 1, 2, 3, 4).

v_1 = (0.1816, 0.0848, 0.1295, 0.1354, 0.1592, 0.0982, 0.1429, 0.0685)

v_2 = (0.1816, 0.1339, 0.0923, 0.0729, 0.1220, 0.1458, 0.0804, 0.1711)

v_3 = (0.1458, 0.1875, 0.0892, 0.0892, 0.0892, 0.0892, 0.1458, 0.0892)

v_4 = (0.0952, 0.0952, 0.1756, 0.0952, 0.1280,0.1637, 0.0952, 0.1161)

step 1.3: We rank the $u_j(j=1,2,3,4,5,6,7,8)$ in a descending order according to the vi (i = 1, 2, 3, 4). Assuming that the weight of u_j is (0.15, 0.10, 0.12, 0.10, 0.12, 0.13, 0.15, 0.13), we use the UEOWA operator to aggregate reference, which is shown in section in step 3 section IV. The result $\tilde{z}_i(w)(i=1,2,3,4)$is shown as the following. It should be noted here that there are several methods to make certain the weight, such as Ordinary Least Squares (OLS). Reference [1] gives an explanation to several methods to make weight.

$\tilde{z}_1$(w) =0.10 X $[s_3,s_4]$ $\oplus$ 0.12 X $[s_2 , s_4]]$ $\oplus$ 0.13 $[s_2 , s_3]$ $\oplus$ 0.15 X$[s_2 , s_3]$ $\oplus$ 0.12 X$[s_1 , s_3]$ $\oplus$ 0.10 X $[s_1 , s_2]$ $\oplus$ 0.13 X$[s_0 , s_2]$ $\oplus$ 0.15 X $[s_0 , s_1]$ = $[s_{1.32} , s_{2.69}]$

$\tilde{z}_2$(w) =0.10 X $[s_5 , s_6]$ $\oplus$ 0.12 X $[s_4 , s_6]$ $\oplus$ 0.13 X$[s_3 , s_5]$ $\oplus$ 0.15 X$[s_3, s_4]$ $\oplus$ 0.12 X$[s_2 , s_4]$ $\oplus$ 0.10 X$[s_1 , s_3]$ $\oplus$ 0.13 X$[s_1 , s_2]$ $\oplus$ 0.15 X[s0 , s2] = $[s_{2.29} , s_{3.71}]$

$\tilde{z}_3$(w) =0.10 X $[s_4 , s_5]$ $\oplus$ 0.12 X$[s_1 , s_3]$ $\oplus$ 0.13 X$[s_1 , s_3]$ $\oplus$ 15 X$[s_1 , s_2]$ $\oplus$ 0.12 X$[s_0 , s_1]$ $\oplus$ 0.10 X$[s_0 , s_1]$ $\oplus$ 0.13 X$[s_{0,} s_1]$ $\oplus$ 0.15 X$[s_0 , s_1]$ = $[s_{0.8} , s_{2.05}]$

$\tilde{z}_4$(w)=0.10 X$[s_2 , s_3]$ $\oplus$ 0.12 X$[s_2 , s_4]$ $\oplus$ 0.13 X$[s_1 , s_2]$ $\oplus$ 0.15 X$[s_0, s_2]$ $\oplus$ 0.12 X$[s_0 , s_1]$ $\oplus$ 0.10 X$[s_0 , s_1]$ $\oplus$ 0.13 X$[s_0, s_1]$ $\oplus$ 0.15 X$[s_0 , s_1]$ =$[s_{0.57}, s_{1.84}]$

step 2:

Comparing each other by using equation (1), we can develop a complementary matrix:

$$P=\begin{bmatrix} 0.5 & 0.1434 & 0.7214 & 0.8030 \\ 0.8566 & 0.5 & 1 & 1 \\ 0.2786 & 0 & 0.5 & 0.6176 \\ 0.1970 & 0 & 0.3824 & 0.5 \end{bmatrix}$$

step 3:

According to equation (3), we can get the ordered vector of v, v = (0.2640, 0.3631, 0.1997, 0.1733). Rank all the alternatives x_i (i =1, 2, 3, 4) according to v in a descending way, and we can get:

$$x_2 \succ x_1 \succ x_3 \succ x_4$$

The result of this method gives an order preference suggestion to the government: alternative x_2 is the most desirable, and alternative x_1 is better than x_3 and x_4. Alternative x_4 is the last one to be selected. It provides an understanding, assessment of which project factors might affect project success.

6.2 Example II of technology project with pair comparison

Let us suppose that there are some technology projects. A government wants to select a best alternative to invest, and experts need to give a suggestion to the government. While in this particular problem, the indicators u_j is defined as the following:

(1) u_1 is complexity technique evaluation,
(2) u_2 is market evaluation
(3) u_3 is input/output evaluation
(4) u_4 is corporation-situation evaluation

x_1, x_2, x_3, x_4 are four alternatives.

To differ from example I, $V1,V2,V3,V4$ are four expert suggestions of pair comparison of the technology projects. We assume that for each indicator, linguistic performance values about the alternatives are provided by means of reciprocal linguistic preference relations, and v_{ij} = Neg (v_{ji}) and v_{ii} = - .

i.e.,

$$V_1=\begin{bmatrix} - & H & L & VH \\ L & - & VL & H \\ H & VH & - & VH \\ VL & L & VL & - \end{bmatrix}$$

$$V_2=\begin{bmatrix} - & H & VL & H \\ L & - & H & VH \\ L & VL & - & VL \\ VH & H & VH & - \end{bmatrix}$$

$$V_3=\begin{bmatrix} - & VH & VL & VH \\ VL & - & L & L \\ VH & H & - & VH \\ VL & H & VL & - \end{bmatrix}$$

$$V_4=\begin{bmatrix} - & M & VL & P \\ M & - & VL & H \\ VL & H & - & VL \\ N & L & VL & - \end{bmatrix}$$

Step 1: The choice of aggregation operator of linguistic information

In section V, part B shows how to obtain the weighting vector. the LOWA operator Q is used to aggregate the individual linguistic performance values. It is an operator guided by a fuzzy linguistic quantifier, Q. We propose to use the linguistic quantifier "Few" with the pair (02, 0.7). For the LOWA operator this quantifier establishes the following weighting vector W =[0.1, 0.5, 0.4, 0], according Eq.(4).

Step 2: Aggregation phase of linguistic information

In the pair comparison matrix $V1,V2,V3,V4$, the four labels { H, H, VH, M }are in the same place row 1, column 2. We aggregate by means of the LOWA operator the four labels. The general expression of the aggregation of labels is :

$$\varnothing(H, H, VH, M) = [0.1, 0.5, 0.4,0]\ (M,VH, H, H)$$
$$= C4\ \{(0.1, M), (0.5, VH), (0.4,H), 0, H)\}$$

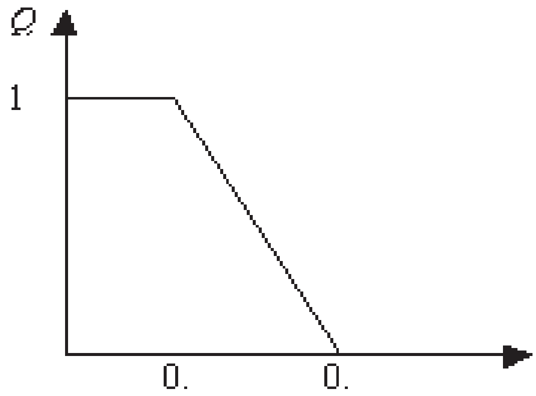

Figure 4. “Few” linguistic quantifier

Then, we obtain the final result applying the recursive definition of the convex combination C_4 as follows. Firstly, we develop until its simpler expression in the following steps:

1. Form = 4,

As 0.56 = 0.5 / (0.5 + 0.4 + 0), 0.44 = 0.4 / (0.5 + 0.4 + 0), 0 = 0 / (0.5 + 0.4 + 0), as mentioned in section V, part A.

2. Form = 3

3. We go back solving the simpler cases until to obtain the final result:

Form = 2,

If andwith,then the convex combination is defined as, as mentioned in section V.

4. Form = 3,

As $VH = s_5$, $H = s_4$

$$\min\{6, 4 + round\,(0.56.(5\text{-}4))\} = 5$$

5. Form = 4,

$$C^4\{(0.1,M), (0.5,VH),(0.4,H),(0,H)\}$$

$$=0.1 \ominus M \oplus C^3\ \{(0.56, VH), (0.44, H), (0,H)\} = M\,(s_3)$$

As $M = s_3$, $VH = s_5$,

$$min(6,3+round(0.1.(5\text{-}3)))=3$$

We just take the above aggregation as an example, and other aggregation is the same reason. Using this aggregation operator the collective linguistic preference relation obtained is the following:

$$V^c = \begin{bmatrix} - & M & VL & VH \\ M & - & VL & H \\ VH & VH & - & VH \\ VL & L & VL & - \end{bmatrix}$$

Step 3: Exploitation phase

Applying the following linguistic choice function [20]:

$$\mu X^c : X \rightarrow S, \mu X^c(x_j) = Min(v^c_{ji}, i = 1, \ldots, n, i \neq j),$$

we obtain the following choice set of alternatives, which is a choice set of greatest alternatives

$$X^c = \{(x_1, VL), (x_2, VL), (x_3, VH), (x_4, VL)\}$$

Rank all the alternatives x_i (i =1, 2, 3, 4) in a descending way , and we can get:

$x_3 \succ x_1 \sim x_4 \sim x_2$

The result of this method gives an order preference suggestion to the government: alternative x_2 is the best assessed one. Alternatives x_1, x_4, x_2 are equivalent.

7. Conclusion and future work

In technology project assessment, linguistic indicators are not unavoidable. A linguistic indicator differs from a numerical one in that its values are not numbers, but words or sentences in a natural or artificial language. And in some situation people is inclined to pair compare reference relation of technology projects,

Meanwhile, Technology projects have their own characteristic. In this paper, according to the activity of technology project evaluation, a set of indicators is proposed based on output and contribution to the society.

To solve the aforementioned problems in technology project assessment, this paper builds a new set of indicators and introduces two aggregation operators in the technology project to deal with two situations of technology project assessment respectively, including linguistic and subjective information and pair comparison of preference relation.

The proposed methods estimate project success based on the proposed indicator system. They provide important support for decision makers. The methods are clearly capable of identifying key technology project characteristics with linguistic and subjective information. It should be useful for anyone who wants to understand the underlying reasons for why some projects turn out better than others. Benefit of the preference matrix is that it creats an overall assessment plan that helps coordinate assessment and research during linguistic decision analysis, reference collection.

It should be noted that different decision maker may have different way or different linguistic scale to evaluate technology project, but it is proved though the example that it is feasible and understandable to use subjective and linguistic information to evaluate technology project by our proposed method. Future work includes weighting of different indicators. This requires that the method is complemented with a way of prioritizing the success indicators in relation to each other.

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