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Decision Making for the Use of Cloud Computing: A Cost and TOE Based Approach

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Abstract: Aimed at the decision-making problem of the application of cloud computing, a new cost and TOE (Technology, Organization and Environment) based approach is proposed. First, this paper argues that cost, as well as TOE factors (Technology, Organization and Environment) should be considered for the use of cloud computing decisions; Second, the method of standard and mean deviation is applied to determine the unknown attribute weights; Finally, based on the LWAA (linguistic weighted arithmetic averaging) operator, calculate the comprehensive evaluation value for the alternative cloud computing providers. Through compared with the calculated values to identify whether the company is suitable for the use of cloud computing. A numerical example is given to illustrate the usefulness of the proposed approach

Keywords: Cloud computing, cost, environment, organization, technology.

1. INTRODUCTION

Cloud computing represents the latest progress in information technology (IT) evolution and refers to an IT service model where computing services (both hardware and software) are delivered on demand to customers over a network in a self-service mode, independent of device and location [1]. Using cloud computing can bring many advantages for firms.

Is cloud computing really suitable for every firms? The answer is may not. A survey conducted by the European Network and Information Security Agency indicates that 68.1% of firms think that the use of cloud computing can avoid capital expenditure in hardware, software, IT supported and 30.6% of firms think the cloud computing can remove economic/expertise barriers impeding to modernize business processes by the introduction of the technology [2]. But some other surveys present that nearly half (48%) of the enterprises are skeptical with cloud computing, even some researches find that using cloud will be more expensive [3].

Therefore, research on the using of cloud computing problems is very important for firms. From the above analysis, we can see that the use of cloud computing decision is essentially a multi-attribute group decision making problem. However, the existing literatures have some drawbacks: (1) In the decision-making process, only consider the subjective (*e.g.* strategy, management, etc) or objective attributes (*e.g.* investment cost), not effective combine them will lead to inaccuracy of decision results; (2) Neglect the attribute weights, or assume that they are already known. However, because every project has its own specific influential factors, neglect or merely subjective assignment of values to attribute weights will increase the uncertainty of the decision-making process.

Therefore, in order to fill the research gap, this study proposes a cost with TOE (Technology, Organization and Environment) criteria, then a novel MAGDM (multi-attribute group decision making) approach is presented to solve the problem. The proposed approach is mainly divided into the following steps: First, collection of decision opinions, establish decision matrices and normalize them; Second, the method of standard and mean deviation is applied to determine the unknown attribute weights; Then, based on the LWAA operator, the preference information is aggregated into the comprehensive evaluation value. Finally, refers to the calculated lower limit and upper limit of scores, and identify whether the company is suitable for the use of cloud computing.

The rest of the paper is structured as follows. Section 2 proposed the performance criteria of a company's suitability for the use of cloud computing. Section 3 introduces the proposed approach and the general steps in the decision analysis. Section 4 then demonstrates a numerical example, and Section 5 presents the conclusions.

2. THE PERFORMANCW CRITERIA OF A COMPANY'S SUITABILITY FOR THE USE OF CLOUD COMPUTING

In this study, we use TOE framework with economic issues to analyze the performance criteria of the use of cloud computing. The TOE framework is widely used to analyze IT use decisions by firms, and it identifiers three context groups: technological, organizational, and environmental. The TOE framework mainly describes the qualitative impact factors. Therefore, combined with cost issues can comprehensive reflected the impact factors involved in using of cloud computing.

2.1. Cost

Cost is the major consideration of a firm to reduce costs of information systems [4]. Due to the characteristics of elas-

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ticity, scalability and pay-per-use of cloud computing [1,5], firms don't need to invest in their own servers or employ staff to take care of them. Instead, they just need to pay for the services on demand [6]. In this dimension, we mainly consider the investment costs include : Compute cost, Storage cost, Transfer cost and Application cost proposed by Misra and Mondal [3].

2.2. Technology

For technology, firms need to find out whether the cloud computing is really superior to the existing IT infrastructure in terms of technology related issues. Embarking on the cloud can be as easy as browsing through a catalogue of IT services, adding them to a shopping cart and submitting the order. As soon as the order is approved by an administrator, the rest of the things are done by cloud [3]. Therefore, cloud computing is more useful, easy and accurate [7, 8]. Therefore, when evaluate this dimension we mainly consider the several aspects: Usefulness, Ease of use, Accuracy, Reliability, Security and Trust [9-13]

2.3. Organization

The organizational context includes attributes such as strategy, top management support, quality of human resources, and managerial skills [14, 15]. Firms can focus on their core activities and outsource noncore IT activities to cloud provider, and make strategic alliance with vendors to make up the shortage of resources [4]. Top management support is critical for creating a supportive climate and for providing adequate resources for the use of new technologies [16]. Using of cloud computing also can enhance the quality of human resources [6]. Therefore, This dimension we consider Strategy, Top management support, Human resources quality and Managerial skills issues [17].

2.4. Environment

Firms also need to consider the environmental attributes such as competitive and trading partner pressure when adopted cloud computing [17]. Competitive pressure refers to the level of pressure felt by the firm from competitors within the industry [18]. Additionally, many studies have suggested that firms rely on trading partners for their IT design and implementation tasks, and trading partner pressure is an important determinant for IT use [9]. Therefore, we consider Competitive pressure and trading partner pressure in environment factor.

3. THE PROPOSED METHOD

An improved MAGDM is proposed to solve the problem; the algorithm for the approach will be developed in the following three major states:

A. Collection of decision opinions and establish decision matrices

A committee of decision-makers is formed to determine whether the company's suitability for the use of cloud computing. The criteria (attributes) can be divided into two categories——objective and subjective— in the decision problem. The subjective attributes are defined qualitatively and assessed in linguistic terms represented by linguistic term. The objective attributes are defined in monetary/quantitative terms. Let $M=\{1,2, \ldots ,m\}$met($m \geq 2$), $N=\{1,2,\ldots ,n\}$($n \geq 2$) and $T=\{1,2,\ldots ,t\}$ ($t \geq 2$); $i \in M$, $j \in N$, $K \in T$: Let $A=\{A_1, A_2 \ldots, A_m\}$ represent a set of *m* feasible alternatives. $U=\{u_1,u_2,\ldots,u_n\}$ represents the set of attributes (criteria), $D=\{d_1,d_2,\ldots,d_t\}$ is a set of DMs. $W=(w_1,w_2,\ldots,w_n)^T$ is the weight vector of tributes, where $w_j \geq 0$, $\sum_{j=1}^{n} w_j = 1$; $w_j \in [0,1]$, $j=1,2,\ldots,n$, $w_j^{(k)}$ is the given weight about *j*th attribute by DM *k*.

Suppose that $S=\{s_i \mid i=-t,\ldots,t\}$ is a finite and ordered discrete term set, where s_i represents a possible value for linguistic variables; for example, a set *S* of nine terms can be:

S = { s_{-4} = *extremely* poor, s_{-3} = *very* poor, s_{-2} = poor, s_{-1} = *slightly* poor, s_0 = fair, s_1 = *slightly* good, s_2 = good, s_3 = *very* good, s_4 = *extremely* good}. As do Herrera *et al.* [19-21], we have the following definitions on set *S*:

(1) The set is ordered: $s_i \geq s_j$ if $i \geq j$;

(2) There is the negation operator: $neg(s_i)=s_{-i}$;

(3) Max operator : $\max(s_i,s_j)=s_i$, if $s_i \geq s_j$;

(4) Min operator: $\min(s_i,s_j)=s_i$, if $s_i \leq s_j$.

The operational laws for set *S* are given as follows [22, 23]:

Let $s_\alpha, s_\beta \in \bar{S}$, $\lambda_1, \lambda_2 \in [0,1]$,

(1) $S_\alpha \oplus S_\beta = S_{\alpha+\beta}$;

(2) $S_\alpha \oplus S_\beta = S_\beta \oplus S_\alpha$;

(3) $\lambda S_\alpha = S_{\lambda\alpha}$;

(4) $(S_\alpha)^\lambda = S_{\alpha^\lambda}$;

(5) $\lambda(S_\alpha \oplus S_\beta) = \lambda S_\alpha \oplus \lambda S_\beta$

(6) $(\lambda_1+\lambda_2)S_\alpha = \lambda_1 S_\alpha \oplus \lambda_2 S_\alpha$

Definition 1: Let $\bar{S}$ be the extended continuous linguistic term set, and $S_i \in \bar{S}$, then the subscript *i* of S_i can be obtained by the following function [24]:

$$I : \bar{S} \to [-t.t],$$

$$I(s_i) = i, s_i \in \bar{S}$$

Definition 2 (Wu and Chen, 2007)**:** Let $\{s_{a_1}, s_{a_2}, \ldots, s_{a_n}\}$ be the linguistic variables set, then

LWAA: $\bar{S}^n \rightarrow \bar{S}$ can be defined as: $LWAA_w(s_{a_1}, s_{a_2}, ..., s_{a_n}) = w_1 s_{a_1} \oplus w_2 s_{a_2} \oplus \cdots \oplus w_n s_{a_n} = s_\alpha$, where $\alpha = \sum_{j=1}^{n} w_j I(s_{a_j})$, $w = (w_1, w_2, ..., w_n)^T$ is the weighting vector of the linguistic variables $s_i (i = 1, 2, ..., n)$, $w_j \in [0,1]$, $i = 1, 2, ..., n$, $\sum_{i=1}^{n} w_i = 1$, and $I(s_{a_j})$ is the subscript of s_{a_j}. Especially, if $w = (1/n, 1/n, ..., 1/n)^T$, the LWAA operator is then reduced to the LAA operator [22].

Suppose each expert is evaluated with respect to the *n* attributes, whose values constitute a decision matrix denoted by

u1 u2 … un

$$X_k = (x_{ij})_{m\times n} = \begin{matrix} A_1 \\ A_2 \\ \vdots \\ A_m \end{matrix} \begin{pmatrix} x_{11} & x_{12} & \cdots & x_{1n} \\ x_{21} & x_{22} & \cdots & x_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ x_{m1} & x_{m2} & \cdots & x_{mn} \end{pmatrix} \quad (1)$$

In order to measure all attributes in dimensionless units and facilitate inter-attribute comparisons, we introduce the following formulas to normalize each attribute value x_{ij} in decision matrix $X = (x_{ij})_{m\times n}$ into a corresponding element r_{ij} in normalized decision matrix given by Eq. (2):

u1 u2 … un

$$R = (r_{ij})_{m\times n} = \begin{matrix} A_1 \\ A_2 \\ \vdots \\ A_m \end{matrix} \begin{pmatrix} r_{11} & r_{12} & \cdots & r_{1n} \\ r_{21} & r_{22} & \cdots & r_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ r_{m1} & r_{m2} & \cdots & r_{mn} \end{pmatrix} \quad (2)$$

where,

$$r_{ij}^{(k)} = \frac{x_{ij}^{(k)}}{\sqrt{\sum_{i=1}^{m} (x_{ij}^{(k)})^2}}$$ for benefit attribute x_{ij},

$i \in M, j \in N$ $$r_{ij} = 1 - \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} (x_{ij})^2}}$$, for cost attribute x_{ij},

$i \in M, j \in N$

B. Determine the weights of attributes

For each alternative $A_i \in A$, DM d_k gives a preference value $x_{ij}^{(k)}$ in regard to the attribute $u_j \in U$, $x_{ij}^{(k)}$ means the assessment information is given by DM *k* about *j*th attribute of alternative A_i, where $x_{ij}^{(k)}$ is in the form of linguistic variable. That is $x_{ij}^{(k)} \in \bar{S}$, then all the alternatives' preference values comprise the decision matrix $X^{(k)} = (x_{ij}^{(k)})_{m\times n}$.

Definition 2: Let $\{s_{a_1}, s_{a_2}, ..., s_{a_n}\}$ be the linguistic variables set, then LWAA: $\bar{S}^n \rightarrow \bar{S}$ can be defined as: $LWAA_w(s_{a_1}, s_{a_2}, ..., s_{a_n}) = w_1 s_{a_1} \oplus w_2 s_{a_2} \oplus \cdots \oplus w_n s_{a_n} = s_\alpha$, where $\alpha = \sum_{j=1}^{n} w_j I(s_{a_j})$, $w = (w_1, w_2, ..., w_n)^T$ is the weighting vector of the linguistic variables $s_i (i = 1, 2, ..., n)$, $w_j \in [0,1]$, $i = 1, 2, ..., n$, $\sum_{i=1}^{n} w_i = 1$, and $I(s_{a_j})$ is the subscript of s_{a_j}. Especially, if $w = (1/n, 1/n, ..., 1/n)^T$, the LWAA operator is then reduced to the LAA operator [22].

Definition 3: Let $s_\alpha, s_\beta \in \bar{S}$ be two linguistic variables, and let $d(s_\alpha, s_\beta) = \| s_\alpha - s_\beta \| =$

$= |\alpha - \beta|$ be the deviation between s_α and s_β [23].

To expert d_k and attribution of u_j, the standard deviation between alternative A_i and others is:

$$S_j^{(k)} = \sqrt{\frac{1}{m}\sum_{i=1}^{m} (\| x_{ij}^{(k)} w_j^{(k)} - \frac{1}{m}\sum_{t=1}^{m} x_{ij}^{(k)} w_j^{(k)} \|)^2}$$
$$= w_J^{(k)} \sigma_j^{(k)},\ j = 1, 2, ..., n \quad (3)$$

where,

$$\sigma_j^{(k)} = \sqrt{\frac{1}{m}\sum_{i=1}^{m} (d(x_{ij}^{(k)}, x_j^{(k)}))^2} \quad (4)$$

$$x_j^{(k)} = \frac{1}{m}\sum_{t=1}^{m} a_j^{(k)}, j = 1, 2, ..., n$$

The mean deviation is:

$$V_j^{(k)} = \frac{1}{m}\sum_{i=1}^{m} \left\| x_{ij}^{(k)} w_j^{(k)} - \frac{1}{m}\sum_{t=1}^{m} x_{tj}^{(k)} w_j^{(k)} \right\| = w_j^{(k)} \delta_j^{(k)},$$
$$j = 1, 2, ..., n \quad (5)$$

where,

$$\delta_j^{(k)} = \frac{1}{m}\sum_{i=1}^{m} d(x_{ij}^{(k)}, x_j^{(k)}) \quad (6)$$

$$x_j^{(k)} = \frac{1}{m}\sum_{t=1}^{m} a_j^{(k)}, j = 1, 2, ..., n$$

Based on the above analysis, the choice of the weighting vector w should maximize the total standard and mean deviation of all the evaluation indices. To do so, the objective function is constructed as follows:

$$\text{Max } F(w)=\sum_{j=1}^{n}(uS_j^{(k)}+vV_j^{(k)}) \quad (7)$$

$$\text{s.t } \sum_{j=1}^{n} w_j^{(k)2}=1, w_j^{(k)}\geq 0$$

$$u+v=1, u\geq 0, v\geq 0$$

where, $S_j^{(k)}$ and $V_j^{(k)}$ denote the standard and mean deviation for attribute u_j of expert d_k, *u* and *v* denote the preferences of the DMs, *u=0* represents the DMs only considering the mean deviation and not the standard deviation=0 represents the DMs only considering the standard deviation and not the mean deviation. $u,v\neq 0$ as of DMs considering both the standard and mean deviations. Then the following model is obtained when considering both the standard and mean deviations:

$$\text{Max } F(w)=\sum_{j=1}^{n} w_j^{(k)}(u\sigma_j^{(k)}+v\delta_j^{(k)}) \quad (8)$$

$$\text{s.t } w_j\geq 0, j=1,2,...,n, \sum_{j=1}^{n} w_j^{(k)2}=1$$

$$u+v=1, u\geq 0, v\geq 0$$

Solving gives:

$$w_j^{(k)}=\frac{u\sigma_j^{(k)}+v\delta_j^{(k)}}{\sqrt{\sum_{j=1}^{n}(u\sigma_j^{(k)}+v\delta_j^{(k)})^2}} \quad (4)$$

By normalizing $w_j^{(k)}$ to let the sum of $w_j^{(k)}$. *j=1,...,n* be a unit, gives:

$$w_j^{*(k)}=\frac{w_j^{(k)}}{\sum_{j=1}^{n} w_j^{(k)}}=\frac{u\sigma_j^{(k)}+v\delta_j^{(k)}}{\sum_{j=1}^{n}(u\sigma_j^{(k)}+v\delta_j^{(k)})}, j=1,2,...n \quad (10)$$

C. Aggregating the comprehensive evaluation value

After the attribute weights vectors are calculated based on the above analysis, then we can aggregating the comprehensive evaluation value by Eq. (11):

$$Z_j=\sum_{k=1}^{t}\lambda_k\sum_{j=1}^{n} w_j^*(x_{ij}^{(k)})_{m\times n} \quad (11)$$

D. Determine whether the company is suitable for the use of cloud computing

In order to better make cloud using decisions, we used the proposed approach to calculate the lower limit value Z_{lower} and upper limit value Z_{upper}. Suppose all decision opinions given by each DMs according to each attributes are "s_{-1} = slightly poor", then we can calculate the lower limit value Z_{lower}. Because if each DM's opinion is just below "s_0=fair", apparently the company is not suitable for using cloud computing. Therefore, Z_{lower} is the lower limit value. If the calculated value *Z* is less than Z_{lower}, the company is certanly not suitable for adopt cloud computing. Similarly, Suppose all deision opinions given by each DMs according to each attributes are "s_1 = slightly good", we can get the upper limit value Z_{upper}. If the calculated value $Z > Z_{upper}$, then the company is certanly suitable for the use of cloud computing. A result obtained between Z_{upper} and Z_{lowe} is considered moderate. Further investigation would be required and other factors at the company level should be taken into consideration in order to arrive at the final decision whether the cloud services would be viable in the long run. Therfore, if $Z > Z_{upper}$, the company is totally suitable for the use of cloud computing; if $Z_{lower}<Z<Z_{upper}$, the company is may or not be suitable for he adoption of Cloud; if $Z < Z_{lower}$, the company is totally not suitable for the use of cloud computing.

4. ILLUSTRATIVE EXAMPLE

This section we use a example to illustrate the usefulness of the proposed approach. In the calculation process, the decision-making steps of the Illustrative example are as follows:

Step 1: A company wants to identify their suitability for the use of cloud computing from Comprehensive consideration of many issues. Four experts $D=\{D_1, D_2, D_3, D_4\}$ are respectively are asked to evaluate the company's suitability for cloud computing using according to the proposed criteria in Section 2: Technology(u_1), Organization(u_2), Environment(u_3), and Investment cost(u_4). These attributes are classifying into two groups (Table **1**). The subjective attributes are defined qualitatively and assessed in linguistic terms, the objective attributes are defined in monetary/quantitative terms:

Table 1. Categorized the use of cloud computing attributes.

Subjective Attributes	Objective Attributes
Technology(u_1) Organization(u_2) Environment(u_3)	Investment cost(u_4)

Step 2: Experts use linguistic term sets to give their decision opinions to the company (Tables **2** and **3**) and the subjective evaluation information for each attributes (Table **4**).

Step 3: Normalize the decision matrix using Eq.(2) as below:

Step 4: Then, using Eq.(10), suppose the objective weights and subjective weights have the equal importance (*u*=*v*=0.5), and compute the integrated weights of attributes as below:

$$w=(0.2365, 0.2230, 0.2150, 0.3255)$$

Step 5: Using LWAA operator to aggregating the decision information and compute the total scores of the company by Eq. (11) as *Z*=0.3544.

Table 2. The decision opinions given by expert.

	u_1	u_2	u_3
D_1	S_2	S_1	S_0
D_2	S_1	S_0	S_1
D_3	S_3	S_0	S_2
D_4	S_2	S_1	S_{-1}

Table 3. The costs under objective attributes.

D_i	CS	SC	TS	AS	C
D_1	22	34	21	34	111
D_2	23	14	19	28	84
D_3	19	21	29	35	104
D_4	22	16	19	21	78

*CS= Compute costs (Million), SC= Storage costs (Million), TS =Transfer costs (Million),
AS= Application costs (Million), C= Total investment costs(u_4)(Million)

Table 5. The decision opinions given by expert.

	u_1	u_2	u_3	u_4
D_1	0.1321	0.6567	0.2500	0.7833
D_2	0.3864	-0.3333	0.2500	0.7345
D_3	0.2146	0	0.1123	0.7525
D_4	0.1429	0.6667	0.3450	0.7310

Step 6: Compute the lower limit value Z_{lower} and upper limit value Z_{upper}. Because we suppose all experts give the same opinions, thus the weights of attributes are equal w =(0.25, 0.25, 0.25, 0.25). Then compute the upper limit value Z_{upper}=0.3102 and lower limit value Z_{lower}=-0.3102.

Step 7: Because the comprehensive evaluation value Z=0.3544 > Z_{upper}=0.3102, thus according to Section 3.4, the company is fully suitable for the use of cloud computing.

5. CONCLUSION

This paper proposes a novel approach to solving the use of cloud computing decision problem. In this approach, this study first proposes a cost with TOE (Technology, Organization and Environment) criteria, rather than a novel MAGDM approach is presented to solve the decision problem. This paper enriches the theory and methodology of use of cloud computing decision-making and MAGDM analysis. The theory and numerical analysis results indicate that the study is useful for the use of cloud computing decision-making and can resolve many other management decision-making problems, such as vendor selection, investment project selection, etc. Future work will focus on using empirical data to verify the approach and extend it to incorporate other factors and methods to make the decision-making process more simple and effective.

CONFLICT OF INTEREST

The authors confirm that this article content has no conflict of interest.

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