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Trust -Based Service Selection in Public Cloud Computing Using Fuzzy Modified VIKOR Method

Hamzeh Mohammd Alabool, Ahmad Kamil Mahmood

Dept. Computer & Information Sciences, Universiti Teknologi PETRONAS (UTP), Perak, Malaysia

Abstract: Recently, resolving the problem of evaluating and selecting the Cloud Infrastructure Service (CIS) according to trust criteria has become a complex software engineering process. Cloud service Providers (CSPs) and Cloud Service Requesters (CSRs)both have to face great uncertainty and complexity regarding the degree of CIS trustworthiness. Therefore, many of the normalization methods have been developed for cost effectiveness and performance criteria. As such, sufficient attention must be given to the trust of cloud service in terms of methods as well as achieving desired values, since the need for more efficient decision making is increasing. This paper proposes a novel hybrid fuzzy multi-criteria group decision making method based on combined fuzzy set and modified VIKOR method, which deals with various types of conflicting and incommensurable trust criteria.

Key words: Infrastructure as a Service, Trust, Fuzzy set, VIKOR.

INTRODUCTION

Public Cloud Service (PCS) market has been growing significantly in the recent years (Marston *et al*, 2011; Li *et al*, 2011). Unlike the private and hybrid clouds used by the organizations internally, public cloud platforms are opened to virtually everyone at the convenience of enabling the user to pay via credit cards online (Foster *et al*, 2008). In PCS, customers can access to tens or perhaps thousands of virtual machines (VMs) on demand within a short period of time on pay-as-you-go basis without any up-front investment (Buyya, 2010).However, PCS consists of three main layers of services which are:

- Software as a Service (SaaS) is considered to provide end users with access to software applications, typically paying per use.
- Platform as a Service (PaaS) allows software developers to access development platform on which to write and deploy their own applications, and
- Infrastructure as a Service (IaaS) provides end users with physical and virtual resources, namely servers, storage, networks, and CPU.

Among the three main layers of cloud computing IaaS has the common interest to all stakeholders (Abbadi and Martin, 2011). It offers services in the virtual environment for deploying, running, provisioning, and managing virtual machines and storage. Exactly, IaaS offers incremental scalability (scale up and down) of computing resources and on-demand storage. Despite a number of the attractive features offered by the IaaS providers, the issue of trust remains a challenge. Trust of IaaS providers is often critical for business success namely to decide on IaaS that are provide maximum level of trustworthiness for hosting their applications and ensure the least regret. Determining levels of trust for IaaS is therefore paramount both for the prospective and existing CSRs, and the competitive environment of the local and international service providers.

The development of IaaS and the increased number of CSPs, it is becoming an important issue for both CSPs and CSRs to be able to make decisions regarding (1) What are the trust criteria based QoS that affecting CSRs of selecting IaaS (2) how to define and evaluate trust according to the unique criteria of IaaS in cloud computing environments (3) how can these IaaS providers improve their trust level of IaaS to meet the needs of CSRs in a fuzzy environment? However, both CSPs and CSRs have to face great uncertainty and complexity regarding the degree of CIS trustworthiness (Abbadi and Martin, 2011). Thus, deciding which CIS can be trust is a daunting task. It requires two elements that are dependent on each other: (1) identification of trust quality model helping CSR and CSP to understand the main criteria that affect the trust degree of CIS (2) development of a method to help CSRs and CSPs to evaluate trust degree of CIS for the following main reasons:

- CSRs need a detailed comparison of CIS alternatives in term of trust to decide which CSP can meet their trust requirements before relaying applications, files, and data to cloud (Alhamad*et al*, 2011; Wang *et al*, 2012, ; Hwang and Li, 2010).
- Many CSPs have no clear knowledge of the degree of trustworthiness their Cloud Service (CS) possesses (Sun *et al*, 2011). CSP needs to know the amount of improvements that must be made to their CIS in order to get the ideal trust level.
- The development of CIS and the increased number of CSPs poses a main challenge for both CSPs and CSRs to make decision regarding which CIS can be trusted prior to data and application migration.

Corresponding Author: Hamzeh Mohammd Alabool, Dept. Computer & Information Sciences, Universiti Teknologi PETRONAS (UTP), Perak, Malaysia

Problem Definition:

There arelimited literatures on CIS evaluation and selection method, specifically those that can be applied for evaluating and selecting CIS based on their ability to meet CSR trust requirements. The primary issues which are not investigated by these methods are:

- The major concern of the cloud evaluation and selection methods lies on certain types of quantifiable criteria of QoS, especially cost and performance. As such, attention should be given to non-quantifiable criteria of QoS especially trust of cloud service.
- The majority of cloud evolution and selection methods rank CSP alternatives based on matching (Concordance) between CSR requirements and CIS features, while rank CSP based on mismatching (Discordance) between CSR requirements and CIS features has been ignored.
- There is limitation from the exist methods to supports CSP to evaluate and compare their CIS with other CSPs in order to identify unimproved gaps with their service. Developing method that helps CSP to evaluate their CIS with respect to other CSPs will lead to the following advantages:

a. Helping CSP to determine the unimproved gap within their CIS.
b. Helping CSP to figure the amount of improvements that must be made to their CIS in order to get the ideal trust level.
c. Improving the comparative advantages among CSPs.
d. Help CSP to price their CIS based on the provided values of quality criteria.
e. Help CSP to have specific knowledge about the value for each quality criterion with respect to other providers.
f. In view of point a, b and e, providing CSP with evaluation method will help them to provide CIS optionsassociated with appropriate monetary values. Each option will reflect guaranteed minimum values of operational quality criteria.

Since the evaluation and selection CIS based on trust tend to involve multiple conflicting and incommensurable criteria. This study seeks to propose an effective trust evaluation and selection method based on combined fuzzy set and modified VIKOR. The propose method will be able to solve multiple criteria decision making problems with conflicting and incommensurable criteria. Such a method can help CSR to decide which CSP can meet their trust requirements before relaying applications, files, and data to cloud. In addition, it also attempts to provide guidance to CSPs to decide prioritize enhancement actions in order to fill the unimproved gap associated with their CIS to achieve ideal trust level.

Related Work:

A number of selection processes have been developed using a wide range of mathematical methods and normalization methods, namely Multiple Criteria Decision Making (MCDM), fuzzy synthetic decision to evaluate Cloud Services (CS's) based on CSR preferences and the likes. For example, Wang *et al* (2012) employed fuzzy synthetic decision to evaluate CSs based on CSR preferences and then adopted Cloud Model that was proposed previously (Wang *et al*, 2011) to compute the uncertainty of CS based on monitored QoS of CS data. Fuzzy logic control was used to obtain the evaluation result of QoS of CS. However, this approach only evaluated the performance of CS in a certain period of time and did not cover other aspects of CSR preferences such as usability, availability, and reliability. Garg*et al*, (2013) presented a framework to systemically evaluate and rank CS by use of Cloud Services Measurement Initiative Consortium (CSMIC) QoS criteria. They suggested Analytic Hierarchy Process (AHP) based ranking mechanism to address the evaluation and selection issue. Nevertheless, they only considered the quantifiable QoS criteria of CSMIC and ignored the non-quantifiable QoS criteria. Alhamad *et al*, (2011) developed fuzzy based model with a set of criteria such as security, availability, usability, and scalability. They considered Sugeno fuzzy inference system for the development of an overall trust rating for a given cloud based e-learning system.

Hwang and Li (2010) proposed a model for performance improvement, financial feasibility, and agility factors impacting the trust degree within CS using fuzzy set theory. These factors were considered as input for Mamdani fuzzy inference system then produced a range of values which could be easily used within implementation level to bring out the trust rating for the CS alternatives.

VlseKriterijumskaOptimizacijaIKompromisnoResenje (VIKOR) is an example of a new entailed MCDM approach used by researchers. This method was favored due to its characteristic PCS applied in decision making problems in subfields of selection, ranking, evaluation either individually (Zardari, and Bahsoon, 2011) orcombined with other models (Chiang, 2009) like AHP (Chen, and Wang, 2009), Analytic Network Process (ANP) (Liu, and Yan, 2007), rough sets (Wu *et al*, 2010), and artificial neural networks (Guo, and Zhang, 2008).

In previous work (Chen, and Li, 2008), Fuzzy VIKOR approach is introduced to choose the best insurance company from five Turkish insurance companies under fuzzy environment and multiple criteria decision making problem. Shemshadi *et al*, (2011) used fuzzy VIKOR method for supplier selection based on entropy value for objective weighting on both qualitative and quantitative criteria. Furthermore, Wang *et al* (2006) developed an application for supplier selection based on VIKOR algorithm with entropy method and Fuzzy Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) with vague sets method. However, Wu and Liu, (2011) developed an evaluation model by integrating Decision Making Trial and Evaluation Laboratory (DEMATEL) method, ANP method, and modified VIKOR method to provide airline websites with a clear knowledge of success of their sites and the effort required to fill the gaps between their website status quo and an ideal website.

Fuzzy Set:

The history of fuzzy set goes back to the year 1965 when Professor LotfiZadeh(1965) introduced this term. The main idea behind fuzzy set is to use linguistic variable to describe fuzzy terms and then map this linguistic variable to numerical variable within two valued sets $\{0, 1\}$ of truth values of Boolean logic and replace these two values by unit interval $[0, 1]$ in the decision making process. Traditional fuzzy set cannot be used to measure alternatives for two reasons which are: (1) their weakness in the distribution importance weights of multiple criteria (2) weakness in the assessment of the alternatives with regard to each criterion. Therefore, after five years both Bellman and Zadeh (1970) presented a methodology called Fuzzy Multi-Criteria Decision Making (FMCDM) in order to resolve this weakness.

In fuzzy set, each membership has a value intermediate between $[0, 1]$, referring to the degree of affiliation of a member of the set. In general, if the element is equal to 0 that means it's completely an outside set, however, if the element is equal to 1, that means it's completely an inside set and if the element has value between 0 and 1 it is a partially inside set (Bellman and Zadeh, 1970).

Let X be the universe of discourse, $X = \{x_1, x_2, \ldots\ldots, x_n\}$. $\widetilde{A}$is a fuzzy set of X that represent a set of order couples $\{(x_1, \mu_{\widetilde{A}}(x_1)), (x_2, \mu_{\widetilde{A}}(x_2)), \ldots\ldots, (x_n, \mu_{\widetilde{A}}(x_n))\}$, $\mu_{\widetilde{A}}: X \to [0, 1]$, is the function of membership grade "Membership Function" of $\widetilde{A}$, and $\mu_{\widetilde{A}}(x_i)$ stands for the membership degree of x_i in $\widetilde{A}$.

A fuzzy number represents a fuzzy subset in the universe of discourse X that is both convex and normal. Triangular Fuzzy Number, Trapezoidal Fuzzy Number, and Bell-Shaped Fuzzy Number are types of membership function. However, among the various types of membership function, this study aims to adopt the type of a triangular fuzzy number. A triangular fuzzy number is a fuzzy number represented by three points(p_1, p_2, p_3) and$(p_1 < p_2 < p_3)$. The interpreted membership functions $\mu_{\widetilde{A}}(x)$ of the fuzzy number $\widetilde{A}$ is:

$$\mu_{\widetilde{A}}(x) = \left\{ \begin{array}{ll} 0, & x < p_1 \\ \dfrac{x - p_1}{p2 - p1}, & p_1 \leq x \leq p_2 \\ 0, & x \leq p_3 \end{array} \right\}$$

The Modified Vikor Method:

VIKOR method (called compromise ranking method) (Opricovic,andTzeng, 2004) is considered as one of the most effective MCDM methods for the purpose of optimization and compromise solution in complex and dynamic process.VIKOR is presented as one of appropriate techniques within MCDM (Shemshadi *et al*, 2011) for the purpose of ranking, sorting and then selecting from a set of alternatives conflicting, and criteria non-commensurable, or set of alternatives against various. Hence, the practical and the closest to the ideal solution called the compromise solution. VIKOR presents ranking index based on multi conflicting and non-commensurable criteria, which involves sorting alternatives based on the degree of closeness alternative to the ideal solution (Tsai,*et al*, 2011).

Initially, VIKOR method begun with the aggregating function (L_p-metric) that developed to deal with multi criteria measure for compromise ranking (Yu, 1973; Zeleny, 1982). The value of $L_{p,j}$ in Eq. 1 indicates the distance of alternative A_j from the ideal solution. In other words, this value provides information about the extent to which alternative A_j is useful and useless; the top alternative will be with the maximum group usefulness for decision-makers and it's the least uselessness. However, each one of the various j Alternatives represented asA_1,A_2, ….,A_j, is measured against the ith criteria, shown by C_i, is denoted by F_{ij}.

$$L_p^j = \left\{ \sum_{i=1}^{n} \left[\frac{W_i(F_i^* - F_{ij})}{F_i^* - F_i^-} \right]^p \right\}^{1/p}$$

$$1 \leq p \leq \infty; \quad j = 1,2, \ldots, J \tag{1}$$

Where:

J : Represents the number of alternatives;

a_j : Indicate to alternatives;

F_{ij}: Represent the evaluation value of the ith criterion for alternativea_j;

L_p^j: Represent the degree of convergence between alternative a_j and ideal solution.

Next, VIKOR considers two distance measurements, "concordance"(S_j) and "discordance"(Q_j).The$\min_j S_j$ represents the best alternative which can offer a maximum group usefulness for the ''most'', and with measure$\min_j Q_j$a represents the minimum of individual useless for the ''opponents''. The values of ranking "concordance"S_j and gap measure "discordance" Q_j for alternative A_j, respectively, with the relations.

$$L_j^{p=1} = S_j = \sum_{i=1}^{n} \left[\frac{W_i\left(F_i^* - F_{ij}\right)}{F_i^* - F_i^-}\right]$$
$$\text{for } j = 1,2,\dots,m \tag{2}$$

$$L_j^{p=\infty} = Q_j = \left\{\mathrm{Max}_i \left[\frac{W_i\left(F_i^* - F_{ij}\right)}{F_i^* - F_i^-}\right]\right\}$$
$$\text{for } j = 1,2,\dots,m \tag{3}$$

According to [46] in the decision-making process of VIKOR method concurrently considers two weights which are (1) criteria weight (W_i) and (2) maximum group utility weight (v). Suppose W_i denotes to relative importance of criteria as computed by the fuzzy logic. As well as, V is introduced in order to express the weight for the strategy of the maximizing group usefulness. Thereafter, VIKOR indexF_j (the value of interests ratio brought by scheme, $j = 1,2, \dots J$) its formula is:

$$F_j = v\left[\frac{(S_j - S^*)}{(S^- - S^*)}\right] + (1 - v)\left[\frac{(Q_j - Q^*)}{(Q^- - Q^*)}\right] \tag{4}$$

Where:
$S^* = \mathrm{Min}_j S_j$, $S^- = \mathrm{Max}_j S_j$,
$Q^* = \mathrm{Min}_j Q_j$, $Q^- = \mathrm{Max}_j Q_j$,

As we mentioned above (v) represents the weights of the largest group's usefulness value, while $(1 - v)$ is the weight of the individual useless. According to (Ou Yang, 2009), Modified VIKOR method differs from traditional VIKOR method as follow:

- The traditional VIKOR method cannot specify the values of performance variations that exist between the status quo and the ideal point. For this reason,
- The positive-ideal value S^* =0; then the negative-ideal value S^-= 1; the positive-ideal value Q^*= 0, and the negative-ideal value Q^-=1 in order to get absolute relations for the index valuesR.
- When v> 0.5 then $0 \le v \le 1$, this indicates S more that Q in Eq. (4). Whereas, when v<0.5 this indicates Q is emphasized more that S.
- When v = 1, it represents a decision making process that cloud uses for the strategy of maximum group utility. Whereas, when v = 0, it represents a decision making process that cloud use the strategy of minimum individual regret.

Further, Eq. (4) will be used on behalf of the traditional Q_j. The weights (W_i) will be remove from Eq. (3). The modified Q_j^{mod} and modified F_j^{mod} index are listed as follows:

$$Q_j^{mod} = \left\{\mathrm{Max}_i \left[\frac{\left(F_i^* - F_{ij}\right)}{F_i^* - F_i^-}\right]\right\}$$
$$\text{for } j = 1,2,\dots,m \tag{5}$$

$$F_j^{mod} = v\left[(S_j - 0)/(1 - 0)\right] + (1 - v)\left[(Q_j - 0)/(1 - 0)\right] \tag{6}$$

With simplifiedF_j^{mod}:

$$F_j^{mod} = v\,(S_j) + (1 - v)Q_j \tag{7}$$

At the end, the alternatives for a compromise solution will be improved depending on the following two conditions C1 and C2.

C1: Acceptable advantage:

$$F(CIS^{(2)}) - F(CIS^{(1)}) \geq R \quad (9)$$

Where:
$CIS^{(1)}$: The alternative;R^{mod} which represent as:

$$R^{mod} = (Max_j F_j^{mod} - Min_j F_j^{mod})/(m-1) \quad (8)$$

Where m is the number of alternatives.
C2: Acceptable stability in decision making: $CIS^{(1)}$ is the best ranked inS_j, or \ and Q_j^{mod} tables with F_j^{mod} ranking. Hence, $CIS^{(1)}$can be the compromise solution only if it satisfies those two conditions. However, if one of these conditions is not satisfied then:
C1 is not satisfied: set of ($CIS^{(1)}$,$CIS^{(2)}$, ….,$CIS^{(e)}$) schemes will be selected as a compromise solution.
C2 is not satisfied: $CIS^{(1)}$,$CIS^{(2)}$ schemes will be selected as a compromise solution.

The Proposed Method for Cloud Service Selection:

This section presents how we extended the modified VIKOR with a fuzzy set to derive a new hybrid method in order to evaluate the trust degree of CIS. Our proposed method consists of nine sequential steps that aim to help both CSR and CSP in order to:

- Provide CSRs detailed comparison of CIS alternatives in terms of trust to decide which CSP can meet their trust requirements before relaying applications, files, and data to cloud.
- Help CSPs to determine the amount of improvements that must be made to their CIS in order to get the ideal trust level.

Step 1: Identify a group of sets of alternatives, criteria, and decision makers as follow:

- A set of X alternatives called: $CIS = \{CIS_1, CIS_2, CIS_3, \ldots, CIS_x\}$;
- A set of Y criteria called:$C = \{C_1, C_2, C_3, \ldots, C_y\}$;
- A set of Z decision makers called: $DM = \{DM_1, DM_2, DM_3, \ldots, DM_z\}$;
- A set of fuzzy rating of $CIS_i (i = 1, 2, 3 \ldots . x)$ and criteria$C_j (j = 1, 2, 3 \ldots . y)$ called:

L $\{l_{ij},\ i = 1, 2, 3 \ldots . x; j = 1, 2, 3 \ldots, y\}$.

Step 2: in this step defining the suitable linguistic variables and defining applicable membership functions will be done. Therefore, Table 1 shows the linguistic variables for the important weight of criteria and Table 2 shows the fuzzy rates of alternatives against criteria. Respectively, figure 1 and figure 2 show the fuzzy membership degree for importance weight of criteria and importance rates of alternatives against criteria.

Table 1: Representing weight of criteria by linguistic variables.

Linguistic Variables	Fuzzy Number
Very Low (VL)	(0.00, 0.00, 0.25)
Low (L)	(0.00, 0.25, 0.50)
Medium (M)	(0.25, 0.50, 0.75)
High (H)	(0.50, 0.75, 1.00)
Very High (VH)	(0.75, 1.00, 1.00)

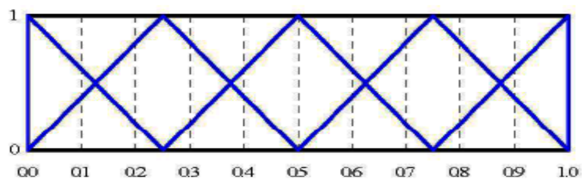

Fig. 1: Representing weight of criteria by linguistic variables

Table 2: Representing fuzzy rates of alternatives against criteria by linguistic variables.

Linguistic Variables	Fuzzy Number
Worst (W)	(0.00, 0.00, 2.50)
Poor (P)	(0.00, 2.50, 5.00)
Fair (F)	(2.50, 5.00, 7.50)
Good (G)	(5.00, 7.50, 10.0)
Best (B)	(7.50, 10.0, 10.0)

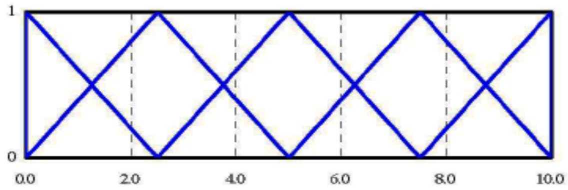

Fig. 2: Representing fuzzy rates of alternatives against criteria by linguistic variables.

Step 3: two main aggregate functions (Eq. 1 and Eq. 2) will be used to compute fuzzy weight of criteria and fuzzy rating of alternative that assigned by decision maker's opinions to construct the decision making matrix. Let the fuzzy rating of i th alternatives regarding j th criterion of k th decision makers be $l_{ijk} = (l_{ijk1}, l_{ijk2}, l_{ijk3})$ and the importance weight of the j th criterion given by k th decision maker be shown as $w_{ijk} = (w_{ijk1}, w_{ijk2}, w_{ijk3})$. Hence, the important weight of each criterion and fuzzy rates of alternatives can be calculated by:

$$w_j = \frac{1}{k}\sum_{k=1}^{k}[w_{jk}] \tag{10}$$

$$l_{ij} = \frac{1}{k}\sum_{k=1}^{k}[l_{ijk}] \tag{11}$$

Then, decision making matrix will be built based on both aggregation functions. Therefore, matrix format can be implemented to solve the selection of suitable CIS problem:

$$D = \begin{bmatrix} l_{11} & l_{12} & \cdots & l_{1n} \\ l_{21} & l_{22} & \cdots & l_{21} \\ \vdots & \vdots & \ddots & \vdots \\ l_{m1} & l_{m2} & \cdots & l_{mn} \end{bmatrix}, \quad W = \begin{bmatrix} w_1 \\ w_2 \\ \vdots \\ w_n \end{bmatrix} \tag{12}$$

Step 4: Center of Area (CoA) defuzzification method will be applied to defuzzify the decision matrix and fuzzy weighs of each criterion and derive their crisp values by using following equation.

$$\frac{\int \mu(x).xdx}{\int \mu(x)dx} \tag{13}$$

To get the ranking index using VIKOR, four steps according to the above mentioned ideas should be applied as follow.

Step 5: Find the top F_i^* values and the lowest F_i^- values for all the criteria, $i = 1,2,..n$ where n represent the number of criteria. Suppose the ith represents a benefit, then:

$$F_i^* = \mathrm{Max}_i F_{ij} \tag{14}$$

$$F_i^- = \mathrm{Min}_i F_{ij} \tag{15}$$

Step 6: Compute the values of ranking "concordance" S_j using Eq. 2 and gap measure "discordance" Q_j^{mod} for alternative A_j using Eq. 5

Step 7: Calculate the VIKOR index F_j^{mod} using Eq. (7).

Step 8: increasing order strategy will be used to rankand sort alternatives based on the values of S_j, Q_j^{mod}, and F_j^{mod}, where the result will grouped as a set of three ranking table.

Step 9: depending on the two conditions C1 and C2, the alternatives for a compromise solution will be improved.

Numerical Example:

This section introduces an example of evaluating and selecting CSPs. Five of CSP alternatives denoted in A, then fifteen criteria have been defined and denoted in C, and a committee of five decision maker (DM)'s denoted in (DM). The steps of the computational are defined as follow:

Step 1: Identify a group of sets of alternatives, criteria, and decision makers as follow:

Assume a CSR X seek to select a the best alternative from set of five alternatives $(CIS_1, CIS_2, CIS_3, CIS_4, CIS_5)$ are to be evaluated by a set of five decision maker (DM)'s $(DM_1, DM_2, DM_3, DM_4, DM_5,)$based on fifteen criteria Auditability (C_1), Compliance (C_2), Contracting experience (C_3), Data Ownership (C_4), Ease of doing business(C_5), Governance (C_6), Ownership (C_7), Provider business stability (C_8), Provider Certifications (C_9), Provider Contract/SLA Verification (C_{10}), Provider Ethicality (C_{11}), Provider Personnel Requirements (C_{12}), Provider Supply Chain (C_{13}), Security Capabilities (C_{14}), Sustainability (C_{15}). The evaluation criteria are selected from Service Measurement Index (SMI) framework developed by CSMIC 2011. According toGarg *et al*, 2013these criteria were used to measure various CSPs characteristic CIS, which is important to build trust of CSRs on any CSP. The DMs have to accomplish the trust criteria of all alternatives and select the best one from the five alternatives in light of the fifteen trust criteria. The research model of this evaluation is shown in figure. 3.

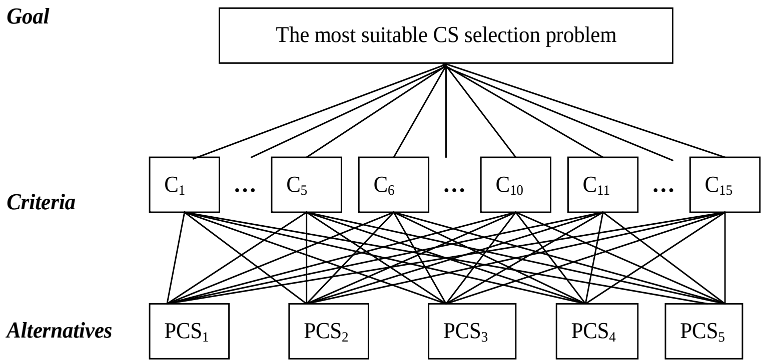

Fig. 3: Research Model.

Step 2: Suitable linguistic terms and relevant membership functions are to be defined by five decision makers as shown in figure 1 and figure 2. Decision makers will use the linguistic terms for assessing the important weight of criteria as appeared in Table 3, and assessing the ratings of alternatives with respect to each criterion as appeared in Table 4.

Table 3: The importance weight for each criterion.

C	**DMs** $(DM_1, DM_2, DM_3, DM_4, DM_5,)$	**C**	**DMs** $(DM_1, DM_2, DM_3, DM_4, DM_5,)$
(C_1)	(H, H, H, VH, H)	(C_9)	(VH, VH, VH, H, H)
(C_2)	(H,VH,VH, H, H)	(C_{10})	(VH, VH, VH, H, H)
(C_3)	(M, H, H, M, M)	(C_{11})	(L, L, M, L, L)
(C_4)	(L, L, M, L, L)	(C_{12})	(H, H, H, VH, H)
(C_5)	(H, M, H, H, H)	(C_{13})	(H, M, H, H, H)
(C_6)	(H, VH, VH, H, H)	(C_{14})	(VH, VH, VH, H, H)
(C_7)	(M, H, M, M, M)	(C_{15})	(H, M, H, M, H)
(C_8)	(H, M, H, M, M)		

Step 3 and Step 4: Convert the linguistic terms into triangular fuzzy numbers and aggregating fuzzy weight of criteria using Eq. (10) and aggregating fuzzy rating of alternatives assigned by decision maker's opinions using Eq. (11) as Table 6. Table 6 represents the decision making matrix that contains all crisp values of weight of criteria and rating of alternatives.

Table 4: Decision making matrix.

Weight	**C**	PCS_1	PCS_2	PCS_3	PCS_4	PCS_5
0.78	(C_1)	7.6	3.3	7.8	2.3	6.5
0.81	(C_2)	4.1	6.0	7.8	3.5	7.8
0.63	(C_3)	6.0	3.8	7.6	2.0	5.0
0.33	(C_4)	7.0	8.5	7.8	6.0	4.0
0.70	(C_5)	3.0	8.5	5.8	7.5	2.3
0.81	(C_6)	2.3	7.0	7.5	1.6	8.1
0.55	(C_7)	5.8	8.5	8.1	6.0	5.0
0.60	(C_8)	7.8	7.5	8.5	7.8	6.6
0.78	(C_9)	5.5	8.1	4.5	3.3	3.5
0.78	(C_{10})	6.3	6.5	5.5	6.0	4.0
0.16	(C_{11})	8.8	7.6	8.1	4.1	8.8
0.78	(C_{12})	5.8	6.0	7.5	3.6	7.6
0.70	(C_{13})	5.1	6.8	4.5	7.0	3.3
0.78	(C_{14})	6.0	7.0	7.5	3.0	5.5
0.58	(C_{15})	3.5	4.5	8.1	3.3	4.5

Step5: Based on Eq. (14) and Eq. (15) best F_i^* values and worst F_i^- values for all the criteria have been determined as appeared in Table 5:

Table 5: Best F_i^* values and worst F_i^- values for all the criteria.

C	BestF_i^* values	Worst F_i^- values	$(F_i^* - F_{ij})$
(C_1)	7.8	2.3	5.5
(C_2)	7.8	3.5	4.3
(C_3)	7.6	2.0	5.6
(C_4)	8.5	4.0	4.5
(C_5)	8.5	2.3	6.2
(C_6)	8.1	1.6	6.5
(C_7)	8.5	5.0	3.5
(C_8)	8.5	6.6	1.9
(C_9)	8.1	3.3	4.8
(C_{10})	6.5	4.0	2.5
(C_{11})	8.8	4.1	4.7
(C_{12})	7.6	3.6	4.0
(C_{13})	7.0	3.3	3.7
(C_{14})	7.5	3.0	4.5
(C_{15})	8.1	3.3	4.8

Step 6 and Step 7: The values of ranking "concordance"S_j have been computed by Eq. (2). While, Eq. (5) is used to compute gap measure "discordance"Q_j^{mod}. The VIKOR indexF_j^{mod} is computed using Eq. (7) by considering $(v = 0.5)$ where v reflects the weight of the strategy of maximizing group usefulness that is assigned using voting by majority of evaluators, while $(1 - v)$ reflects the weight of individual uselessness.

Table 6: The ranking of CIS in ascending order by S, R and Q.

	Alternatives				
	CIS_1	CIS_2	CIS_3	CIS_4	CIS_5
S_j	5.1	3.0	1.9	7.1	5.6
Q_j^{mod}	0.95	0.81	0.75	1.00	1.00
F_j^{mod}	3.0	1.9	1.3	4.2	3.3

Step 8: The values of S_j,Q_j^{mod} and F_j^{mod} ranked and sort in an increasing order, where the result can be seen in Table (9).

Table 7: The ranking of CISs in increasing order byS_j,Q_j^{mod} andF_j^{mod} .

Rank By	S_j	$CIS_4 > CIS_5 > CIS_1 > CIS_2 > CIS_3$
	Q_j^{mod}	$CIS_3 > CIS_2 > CIS_1 > CIS_5$, CIS_4
	F_j^{mod}	$CIS_3 > CIS_2 > CIS_1 > CIS_5 > CIS_4$

Table 8: Ranking of the five CIS by F_j^{mod} mod in the six scenarios.

Alternative	Scenario 1		Scenario 2		Scenario 3		Scenario 4		Scenario 5		Scenario 6	
	V=0		V=0.2		V=0.4		V=0.6		V=0.8		V=1.0	
	Value	Ranking	Value	Ranking	Value	Ranking	Value	Ranking	Value	Ranking	Value	Ranking
PCS_1	0.95	3	1.87	3	2.61	3	3.44	3	4.27	3	5.1	3
PCS_2	0.81	2	1.25	2	1.68	2	2.12	2	2.56	2	3.0	2
PCS_3	0.75	1	0.98	1	1.21	1	1.44	1	1.67	1	1.9	1
PCS_4	1.00	4	2.28	5	3.56	5	4.84	5	6.12	5	7.4	5
PCS_5	1.00	4	1.92	4	2.84	4	3.76	4	4.68	4	5.6	4
Compromise solutions	CIS_3, CIS_2		CIS_3		CIS_3		CIS_3		CIS_3		CIS_3	

Step 9: using on Eq. (8) the compromise solution (See Table 11) can be defined as follow:

Table 9: Compute compromise solution.

$Max_j F_j^{mod}$	$Min_j F_j^{mod}$	R^{mod}
4.2	1.3	0.25

$4.2 - 1.3 \geq 2.5 \rightarrow 2.9 \geq 0.25$

Hence, CIS_3has an acceptable advantage. Furthermore, CIS_3 is the best ranked in Q_j^{mod}, table with F_j^{mod}ranking. Hence, CIS_3can be the compromise solution because it satisfies those two conditions.

Furthermore, to deal with the evaluators preferences six sets of different weight values have been associated with the six scenarios analysis for evaluating CISs. The benefit of providing these different scenarios analysis is to cope with changes in parameter. However, voting by majority (v) plays an important role in the ranking of alternatives.

Table 8 shows six sets of different weight values between zero and one. In table 10 CIS_3 and CIS_2 were the compromise sets for scenario 1. While, CIS_3 was the best ranked, with an acceptable advantage, from scenario 2 to scenario 6.

Conclusion:

It has been observed that the trust issue is critical to external people as well as different providers of the ever-growing cloud computing market. CSPs and CSRs alike have to face great uncertainty and complexity regarding the degree of CIS trustworthiness and reliability. Therefore, this paper introduced a fuzzy modified VIKOR to evaluate and select the most suitable CIS and provideguidance to CSRs on how to improve overall CIS in term of trust. Furthermore, this study showed that DMs can select an appropriate weight based on their needs and preferences in order to make a suitable decision. In the future, we will extend our evaluation method to cover the mismatch problem that can occur between the CSRs trust requirements and what is provided by the CSPs. We will also extend the quality model to cover the common trust criteria such as (integrity, security, privacy, etc…). Defining common trust criteria will assist in making a comprehensive evolution and provide both CSR and CSP with high value information to take the most suitable decision. Expert technique will be used to evaluate the complete quality model.

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