NSS
Neutrosophic Sets and Systems, Vol. 48, 2022
University of New Mexico

An Intelligent Model to Rank Risks of Cloud Computing based on Firm's Ambidexterity Performance under Neutrosophic Environment

Mahmoud Ismail[1], Nayef Alrashidi[2], Nabil Moustafa[3]

[1]Faculty of computers and Informatics, Zagazig University, Zagazig, 44519, Egypt; Email : mahsabe@yahoo.com
[2]Faculty of computers and Informatics, Zagazig University, Zagazig, 44519, Egypt
[3]Faculty of computers and Informatics, Zagazig University, Zagazig, 44519, Egypt

***Correspondence:** mahsabe@yahoo.com

Abstract: In recent years, cloud computing has emerged as a revolutionary technology that offers several benefits to businesses; nevertheless, like any other technology, it comes with significant risks. Firms can gain a competitive advantage by investing in cloud computing while simultaneously exploring new opportunities and leveraging their existing knowledge and capabilities. Cloud computing dangers, on the other hand, may limit these capabilities. We have shown that prospective cloud computing risks have a considerable impact on organizations' performance in two key areas of explorative and exploitative innovation using the ambidexterity theoretical lens. To achieve these goals, the Neutrosophic VlseKriterijumska Optimizcija I Kaompromisno Resenje in Serbian (VIKOR) and multi-attributive border approximation area comparison (MABAC) techniques were used, in which the Neutrosophic approach aids experts in expressing their opinions using linguistic variables, and the VIKOR and MABAC techniques rank cloud computing risks based on ambidexterity criteria. There are eight criteria and ten alternatives are used in this study.

Keywords: Cloud Computing; Risks; Neutrosophic; Uncertainty; VIKOR; MABAC

1. Introduction

Firms have placed a greater emphasis on public computing infrastructure in recent years [1]. Based on cloud computing, it is estimated that organizations have experienced a $3.3 trillion shift in their computer performance [2]. Cloud computing is a computing model that involves the deployment of enormous data centers with efficient processor equipment [3]. By implementing cloud computing technologies, businesses can reap numerous benefits, including reduced investment costs [4]. Cloud computing has also improved the firm's agility by providing flexibility and on-demand services [5-6]. Cloud computing has been cited as a good example of how to improve your business [7]. Though cloud computing is gaining a lot of traction in many industries, it, like any other technology, comes with significant hazards [8]. The most significant hazards of cloud computing implementation, according to past research, are "authentication," "data security, and privacy." [9-11] "confidentiality," "integrity," "availability" [12], "accountability," and "accessibility" [13]. Because risks can have direct and indirect negative effects on service quality, it's critical to have a thorough awareness of them, especially for a newly created technology [10]. Cloud computing plays an important role in strong company innovation since it provides a huge number of innovation opportunities, such as novel computing capabilities and solutions [14]. Though, cloud computing systems' innovative performance is affected by unpredictability and risk issues.

Exploration and exploitation are two methods for obtaining innovative results. The former relates to gathering information and benefiting from new opportunities by investigating new possibilities; the latter, on the other hand, focuses on producing value by taking into account current prospects [15]. Businesses that use both exploration and exploitation at the same time might profit from ambidexterity performance in this way [16]. To put it another way, while exploitation focuses on increasing business productivity and efficiency by deploying current knowledge, exploration focuses on getting innovative and recent technologies and resources by producing and acquiring new knowledge [17-18]. Exploration and exploitation innovations rely heavily on information technology, which may lead to the development of new goods and services for new consumers as well as the extension of existing products and services for existing customers. As a consequence, businesses may achieve long-term success in a changing environment [19].

Exploitation competency may be gained by conserving and leveraging current innovative skills, processes, and knowledge, whereas exploration competency can be gained through recreating knowledge and abilities [20]. The capacity of a company to explore and exploit new opportunities while reacting quickly to market changes results in ambidextrous success [21]. Ambidexterity characteristics help cloud computing corporations to be flexible in an unpredictable market, suggesting that businesses can gain a competitive edge by leveraging dynamic skills. In moderately dynamic markets, exploration capabilities such as deploying routines and codified knowledge are expected; however, in high-velocity markets, exploration capabilities should be strengthened [22]. Because risks influence how businesses spend their dualities (exploration and exploitation) [23]. To ensure that cloud computing systems work well, researchers focused on limiting the influence of risk factors [24]. For example, the cloud computing environment's cyber security risk results in poor service level performance [25]. Another research found that IT infrastructure improves ambidexterity performance and helps firms function more efficiently [26], [27]. Firms' flexibility, agility, cost-effectiveness, and scalability may all benefit from cloud computing, according to it is cited. Furthermore, it can be beneficial in facilitating the rapid introduction of startups to the market, although cloud computing risks might have a detrimental impact on a firm's performance [28]. According to another research, organizations place a high value on data kept in cloud computing infrastructures, which are vulnerable to a variety of dangers. As a result, if such risks materialize, corporations will encounter major problems in carrying out their exploratory and exploitative performance [29]. Furthermore, successful cloud computing adoption may have a favorable impact on a company's performance since it merges internal IT skills, human, and physical resources to operate and improve operations [2]. When security concerns are taken into account, cloud computing encourages inventive performance, particularly when it comes to bringing new goods and services to market [30]. Indeed, cloud computing may lead to inter-organizational innovation that makes use of external knowledge, skills, and production facilities while also maximizing internal knowledge and production capabilities. Various cloud computing concerns, including as economic risks, service availability risks, and data security risks, might be overlooked. It will be steered toward a low adoption rate [31]. It is reasonable to assume that if cloud computing infrastructure is exposed to hazards, this will have a negative influence on business performance.

As a result, the primary purpose of this study is to identify cloud computing risks, followed by a gap analysis of the influence of risks on company performance using organizational ambidexterity theory. As a result, the given theory is used to answer the following research question: what are the top cloud computing risks? To answer the study's main issue, we first assemble previously researched cloud computing risk indicators, then rank them using neutrosophic VIKOR and MABAC approaches based on ambidexterity measurements (Exploration and Exploitation). In various fields, neutrosophic VIKOR and MABAC have been effectively employed to solve neutrosophic multi-criteria decision-making problems [32-39]. However, it has never been used to mitigate the hazards associated with cloud computing. This research makes several contributions. For starters, cloud computing risk concerns have been discovered from a much broader perspective. Second, selected risk variables are prioritized using ambidexterity measures using the neutrosophic VIKOR and MABAC approaches, which is the first research of cloud computing risk factors.

Section 2 provides the related works of cloud computing risks. Section 3 shows the methodology of this paper. Section 4 shows the case study and application of methodology. Section 5 refers to the conclusion of this paper.

2. Related Works

Table 1. show the previous research on the risks of cloud computing.

Table 1. Prior study on cloud computing risk ranking

Reference	Prioritizing cloud computing risks
Dutta et al .[40]	Cloud computing dangers were found in this study, and the ten most significant ones were chosen by creating a risk score based on three factors: chance, effect, and frequency.
Elzamly et al. [41]	Based on Delphi research, the study identified and prioritized important security concerns in cloud computing for financial firms.
Boutkhoum et al. [42]	In this study, a fuzzy AHP-PROMETHEE is employed to determine the best appropriate cloud computing for large data.
Boutkhoum et al. [43]	The authors employed the AHP-TOPSIS approach to assessing cloud computing services to better manage big data in this study.
Amini et al. [44]	To rank cloud computing hazards, fuzzy logic was used in this study. The severity and likelihood criteria were used for assessment.
Henriques de Gusma˜o et al [45]	The authors of this work examine cyber security threats using fault tree analysis and fuzzy decision theory.
Patel and Alabisi [46]	Cloud computing threats were classified in this study into many categories. Customers, service providers, and the government are all taken into account when identifying hazards.
Krishnaveni and Prabakaran [47]	Researchers used machine learning classifier methods to classify cloud computing network intrusion and assaults in this study. SVM, Naive Bayes, and Logistic regression algorithms were used, and the approaches were assessed based on accuracy and reaction time.

Swathy Akshaya and Padmavathi [48]	A taxonomy of cloud computing dangers has been presented in this work. The service delivery paradigms "software as a service," "platform as a service," and "infrastructure as a service" were used to create the categorization.
Jouini et al. [49]	Security threats associated with cloud computing infrastructures were categorized in this study, and new information security metrics were provided based on quantitative analysis.
Sheehan et al. [50]	The cyber security risk of cloud computing has been categorized in this study. In addition, proactive and reactive obstacles to minimizing such hazards have been identified. To assess cyber security risk, likelihood and severity/impact criteria have been implemented, which aid in quantifying those risks.
Mohammad Taghi Taghavifard & Setareh Majidian [51]	This study used the Fuzzy VIKOR Technique to identify cloud computing risks based on a firm's ambidexterity performance.
This study	In this study, we used the neutrosophic sets hybrid with the MCDM methods like neutrosophic VIKOR and MABAC to compute the weights of criteria and rank of risks (alternatives).

3. Methodology

In this section, we provide some definitions in neutrosophic sets and we introduce the neutrosophic VIKOR and MABAC methods. we use $P_a = \{1,2, \dots, a\}$ and $P_b = \{1,2, \dots, b\}$ as an index set for $a \in \mathbb{N}$ and $b \in \mathbb{N}$, respectively.

3.1 Definitions

Definition 1: [52] Make X become a universe. The definition of a neutrosophic set Y over X is:

$$Y = \{< V, (T_Y(V), I_Y(V), F_Y(V)) >: V \in X\}.$$

where $T_Y(V)$, $I_Y(V)$,, and $F_Y(V)$ are the truth-membership, indeterminacy-membership, and falsity membership functions, respectively. They are described as follows:

$$T_Y: X \longrightarrow]\ 0^-, 1^+[, I_Y: X \longrightarrow]\ 0^-, 1^+[, F_Y: X \longrightarrow]\ 0^-, 1^+[$$

Such that $0^- \leq T_Y(V) + I_Y(V) + F_Y(V) \leq 3^+$.

Definition 2: [52] Assume X be a universe. A single-valued neutrosophic set (SVN-set) over X is a neutrosophic set over X, but the truth-membership function, indeterminacy membership function, and falsity-membership function are respectively described as:

$$T_Y : X \longrightarrow [0,1], \quad I_Y : X \longrightarrow [0,1], F_Y : X \longrightarrow [0,1]$$

Such that $0 \leq T_Y(V) + I_Y(V) + F_Y(V) \leq 3$

Definition 3: [52] Assume $h_{\overline{k}}, g_{\overline{k}}, j_{\overline{k}} \in [0,1]$ be any real numbers, $n_w, m_w, o_w, q_w \in \mathbb{R}$ and , $n_w \leq m_w \leq o_w \leq q_w$ $(w = 1,2,3)$ Then a single valued neutrosophic number (SVNN)

$$\hat{y} = \langle \left((n_1, m_1, o_1, q_1), h_{\overline{k}} \right), \left((n_2, m_2, o_2, q_2), g_{\overline{k}} \right), \left((n_3, m_3, o_3, q_3), j_{\overline{k}} \right) \rangle$$

is a special neutrosophic set on the set of real numbers $\mathbb{R}$, whose truth-membership function $b_{\overline{k}}$, indeterminacy membership function $c_{\overline{k}}$ and falsity-membership function $d_{\overline{k}}$ are respectively described as:

$$b_{\overline{k}} : \mathbb{R} \longrightarrow \left[0, h_{\overline{k}}\right], b_{\overline{k}}(V) = \begin{cases} f_b^1(V), & n_1 \leq V < m_1 \\ h_{\overline{k}}, & m_1 \leq V < o_1 \\ f_b^e(V), & o_1 \leq V < q_1 \\ 0, & otherwise \end{cases}$$

$$c_{\overline{k}} : \mathbb{R} \longrightarrow \left[g_{\overline{k}}, 1\right], c_{\overline{k}}(V) = \begin{cases} f_c^1(V), & n_2 \leq V < m_2 \\ g_{\overline{k}}, & m_2 \leq V < o_2 \\ f_c^e(V), & o_2 \leq V < q_2 \\ 1, & otherwise \end{cases}$$

$$d_{\overline{k}} : \mathbb{R} \longrightarrow \left[j_{\overline{k}}, 1\right], d_{\overline{k}}(V) = \begin{cases} f_d^1(V), & n_3 \leq V < m_3 \\ j_{\overline{k}}, & m_3 \leq V < o_3 \\ f_d^e(V), & o_3 \leq V < q_3 \\ 1, & otherwise \end{cases}$$

Where the functions $f_b^1 : [n_1, m_1] \longrightarrow \left[0, h_{\overline{k}}\right]$, $f_c^e : [o_2, q_2] \longrightarrow \left[g_{\overline{k}}, 1\right]$, $f_d^e : [o_3, q_3] \longrightarrow \left[j_{\overline{k}}, 1\right]$ are continuous and non-decreasing , and satisfy the conditions: $f_b^1(n_1) = 0, f_b^1(m_1) = h_{\overline{k}}$, $f_c^e(o_2) = g_{\overline{k}}$, $f_c^e(q_2) = 1, f_d^e(o_3) = j_{\overline{k}}, f_d^e(q_3) = 1$ functions $f_b^e : [o_1, q_1] \longrightarrow \left[0, h_{\overline{k}}\right]$, $f_c^1 : [n_2, m_2] \longrightarrow \left[g_{\overline{k}}, 1\right]$, $f_d^1 : [n_3, m_3] \longrightarrow \left[j_{\overline{k}}, 1\right]$ are continuous and nodecreasing , and satisfy the conditions: $f_b^e(o_1) = h_{\overline{k}}, f_b^r(q_1) = 0$, $f_c^1(n_2) = 1$, $f_c^1(m_2) = g_{\overline{k}}, f_d^1(n_3) = 1, f_d^1(m_3) = j_{\overline{k}}$. $[m_1, o_1], n_1$ *and* q_1 For the truth-membership function, the mean interval and the lower and higher limits of the general neutrosophic number $\overline{k}$, respectively. $[m_2, o_2], n_2$ *and* q_2 For the indeterminacy-membership function, the mean interval, and the lower and higher limits of the general neutrosophic number $\overline{k}$, respectively. $[m_3, o_3], n_3$ *and* q_3 For the falsity-membership function, the mean interval, and the lower and higher limits of the general neutrosophic number $\overline{k}$, respectively. The maximum truth-membership degree, minimum indeterminacy-membership degree, and minimum falsity-membership degree are $h_{\overline{k}}$, $g_{\overline{k}}$, and $j_{\overline{k}}$, respectively.

Definition 4: [53] Assume $\overline{k} = \langle (n_1, m_1, o_1, q_1); h_{\overline{k}}, g_{\overline{k}}, j_{\overline{k}} \rangle$, $\overline{kk} = \langle (n_2, m_2, o_2, q_2); h_{\overline{kk}}, g_{\overline{kk}}, j_{\overline{kk}} \rangle$ be two SVNNs and a constant $s \neq 0$ be any real number then:

$$\overline{k} + \overline{kk} = \langle (n_1 + n_2, m_1 + m_2, o_1 + o_2, q_1 + q_2); h_{\overline{k}} \wedge h_{\overline{kk}}, g_{\overline{k}} \vee g_{\overline{kk}}, j_{\overline{k}} \vee j_{\overline{kk}} \rangle$$

$$\overline{k}\,\overline{kk} = \begin{cases} \langle (n_1 n_2, m_1 m_2, o_1 o_2, q_1 q_2); h_{\overline{k}} \wedge h_{\overline{kk}}, g_{\overline{k}} \vee g_{\overline{kk}}, j_{\overline{k}} \vee j_{\overline{kk}} \rangle \ (q_1 > 0, q_2 > 0) \\ \langle (n_1 q_2, m_1 o_2, o_1 m_2, q_1 n_2); h_{\overline{k}} \wedge h_{\overline{kk}}, g_{\overline{k}} \vee g_{\overline{kk}}, j_{\overline{k}} \vee j_{\overline{kk}} \rangle \ (q_1 < 0, q_2 > 0) \\ \langle (q_1 q_2, o_1 o_2, m_1 m_2, n_1 n_2); h_{\overline{k}} \wedge h_{\overline{kk}}, g_{\overline{k}} \vee g_{\overline{kk}}, j_{\overline{k}} \vee j_{\overline{kk}} \rangle \ (q_1 < 0, q_2 > 0) \end{cases}$$

$$s\overline{k} = \begin{cases} \langle (sn_1, sm_1, so_1, sq_1); h_{\overline{k}}, g_{\overline{k}}, j_{\overline{k}} \rangle \ (s > 0) \\ \langle (sq_1, so_1, sm_1, sn_1); h_{\overline{k}}, g_{\overline{k}}, j_{\overline{k}} \rangle \ (s < 0) \end{cases}$$

Definition 5: Assume $\overline{k} = \langle (n_1, m_1, o_1,); h_{\overline{k}}, g_{\overline{k}}, j_{\overline{k}} \rangle$, $\overline{kk} = \langle (n_2, m_2, o_2,); h_{\overline{kk}}, g_{\overline{kk}}, j_{\overline{kk}} \rangle$ be two SVNNs and a constant $s \neq 0$ be any real number then:

$$\overline{k} + \overline{kk} = \langle (n_1 + n_2, m_1 + m_2, o_1 + o_2); h_{\overline{k}} \wedge h_{\overline{kk}}, g_{\overline{k}} \vee g_{\overline{kk}}, j_{\overline{k}} \vee j_{\overline{kk}} \rangle$$

$$\overline{k}\,\overline{kk} = \begin{cases} \langle (n_1 n_2, m_1 m_2, o_1 o_2); h_{\overline{k}} \wedge h_{\overline{kk}}, g_{\overline{k}} \vee g_{\overline{kk}}, j_{\overline{k}} \vee j_{\overline{kk}} \rangle \ (o_1 > 0, o_2 > 0) \\ \langle (n_1 o_2, m_1 m_2, o_1 n_2); h_{\overline{k}} \wedge h_{\overline{kk}}, g_{\overline{k}} \vee g_{\overline{kk}}, j_{\overline{k}} \vee j_{\overline{kk}} \rangle \ (o_1 < 0, o_2 > 0) \\ \langle (o_1 o_2, m_1 m_2, n_1 n_2); h_{\overline{k}} \wedge h_{\overline{kk}}, g_{\overline{k}} \vee g_{\overline{kk}}, j_{\overline{k}} \vee j_{\overline{kk}} \rangle \ (o_1 < 0, o_2 > 0) \end{cases}$$

$$s\overline{k} = \begin{cases} \langle (sn_1, sm_1, so_1); h_{\overline{k}}, g_{\overline{k}}, j_{\overline{k}} \rangle \ (s > 0) \\ \langle (sq_1, so_1, sm_1); h_{\overline{k}}, g_{\overline{k}}, j_{\overline{k}} \rangle \ (s < 0) \end{cases}$$

Definition 6: A single valued trapezoidal neutrosophic number $\overline{k} = \langle (n, m, o, q); h_{\overline{k}}, g_{\overline{k}}, j_{\overline{k}} \rangle$

is a special neutrosophic set on the set of real numbers $\mathbb{R}$, whose truth-membership function, indeterminacy membership function and falsity-membership function are respectively described as:

$$b_{\overline{k}}(V) = \begin{cases} (v - n) h_{\overline{k}} / (m - n), & n \leq V < m \\ h_{\overline{k}}, & m \leq V < o \\ (q - v) h_{\overline{k}} / (q - o), & o \leq V < q \\ 0, & otherwise \end{cases}$$

$$c_{\overline{k}}(V) = \begin{cases} \big(m - v + c_{\overline{k}}(v - n)\big) / (m - n), & n \leq V < m \\ c_{\overline{k}}, & m \leq V < o \\ \big(v - o + c_{\overline{k}}(q - v)\big) / (q - o), & o \leq V < q \\ 0, & otherwise \end{cases}$$

$$d_{\overline{k}}(V)=\begin{cases}\left(m-v+d_{\overline{k}}(V)(v-n)\right)/(m-n), & n\le V<m\\ c_{\overline{k}}, & m\le V<o\\ \left(v-o+d_{\overline{k}}(V)(q-v)\right)/(q-o), & o\le V<q\\ 0, & otherwise\end{cases}$$

respectively.

Definition 7: A single valued trapezoidal neutrosophic number $\overline{k}=\langle(n,m,o);h_{\overline{k}},g_{\overline{k}},j_{\overline{k}}\rangle$

is a special neutrosophic set on the set of real numbers $\mathbb{R}$, whose truth-membership function, indeterminacy membership function and falsity-membership function are respectively described as:

$$b_{\overline{k}}(V)=\begin{cases}(v-n)h_{\overline{k}}/(m-n), & n\le V<m\\ (o-v)h_{\overline{k}}/(o-m), & m\le V\le o\\ 0, & otherwise\end{cases}$$

$$c_{\overline{k}}(V)=\begin{cases}\left(m-v+c_{\overline{k}}(v-n)\right)/(m-n), & n\le V<m\\ \left((m-o)c_{\overline{k}}(o-m)\right)/(o-m), & m\le V\le o\\ 0, & otherwise\end{cases}$$

$$d_{\overline{k}}(V)=\begin{cases}\left(m-v+d_{\overline{k}}(V)(v-n)\right)/(m-n), & n\le V<m\\ \left((v-m)d_{\overline{k}}(V)(o-v)\right)/(o-m), & m\le V\le o\\ 0, & otherwise\end{cases}$$

respectively.

3.2 Phases of the proposed model for Cloud Computing

In this subsection, we provide two phases

Phase I: The Neutrosophic VIKOR Procedure

Stage 1: Form a committee of experts to decide on the aim, alternatives, and criteria.

Stage 2: Draw and create the language scales that will be used to characterize experts, as well as the alternatives.

Stage 3: Collect the opinions of the experts on each component.

Stage 4: Covert opinions of experts to the SVNNs

Stage 5: Compute the score function, by converting the three values of SVNNs into a one value by

$$S(V) = \frac{2 + T(V) - I(V) - F(V)}{3}$$

Stage 6: Compute the weights of criteria by the average method as:

$$W_a = \frac{S_1(V) + S_2(V) + \cdots . S_a(V))}{a}$$

Where a refers to number of criteria.

Stage 7: Construct an evaluation matrix by opinions of experts then average these opinions to obtain one decision matrix

$$V = \begin{pmatrix} V_{11} & \cdots & V_{1a} \\ \vdots & \ddots & \vdots \\ V_{b1} & \cdots & V_{ba} \end{pmatrix}$$

Stage 8: Compute the best and worst solution

${L_a}^{+} = \max V_{ba}$ for positive criteria

${L_a}^{-} = \min V_{ba}$ for negative criteria

Stage 9: Compute the Z_a, U_a values:

$$Z_a = \sum\nolimits_{b=1}^{a} W_a * \frac{{L_a}^{+} - V_{ba}}{{L_a}^{+} - {L_a}^{-}}$$

$$U_a = \max_b (W_a * \frac{{L_a}^{+} - V_{ba}}{{L_a}^{+} - {L_a}^{-}})$$

Stage 10: Compute the value of R_a as:

$$R_a = d\left(\frac{Z_a - \min\limits_b Z_a}{\max\limits_b Z_a - \min\limits_b Z_a}\right) + (1 - d)\left(\frac{U_a - \min\limits_b U}{\max\limits_b U_a - \min\limits_b U_a}\right)$$

Where d =0.5

Stage 11: Rank alternatives according to ascending order of the previous step

Phase II: The Neutrosophic MABAC Procedure

Stage A: Use the previous steps to obtain the opinions of experts then convert them into a single value by a score function, then aggregate these opinions into one matrix.

Stage B: Normalize the decision matrix as:

$\boldsymbol{N_{ba}} = \frac{V_{ba} - L_a^{-}}{L_a^{+} - L_a^{-}}$ for positive criteria

$N_{ba} = \frac{V_{ba} - L_a^{+}}{L_a^{-} - L_a^{+}}$ for cost criteria

Stage C: Compute the weighted normalized decision matrix as:

$$WN_{ba} = W_a + W_a * N_{ba}$$

Stage D: Compute the border approximation area as:

$$Bor_{ba} = (\prod_{a=1}^{b} WN_{ba})^{1/b}$$

Stage E: Compute the distance from the Bor_{ba}

$$DIS_{ba} = WN_{ba} - Bor_{ba}$$

Stage F: The alternatives are ranked based on the descending value of the previous step.

Fig 1. The eight criteria used in this study

4. Case Study: Results and Analysis

Based on the literature, cloud computing risks have been highlighted in this study. The case study is made in a firm in Egypt, which is a new cloud computing company. Experts are a group of three people. Experts will evaluate eight criteria and ten alternatives. The criteria and alternatives in Fig 1 and Fig 2. Then replace their opinions with the scale of SVNNs as in [54]. Then apply the steps of neutrosophic VIKOR and MABAC methods to obtain the weights of criteria and rank of alternatives.

Phase I: Obtaining the weights of criteria by applying the score function to obtain one value then applying the average method. The weights of the criteria are presented in Table 2.

Table 2. The weights of criteria.

Criteria	COM_1	COM_2	COM_3	COM_4	COM_5	COM_6	COM_7	COM_8
Weights	0.1744	0.0817	0.0817	0.0604	0.1744	0.1744	0.1921	0.0604

Phase II: Rank alternatives by the VIKOR and MABAC. Let experts evaluate the decision matrix, then apply the score function to obtain one value, then aggregate three decision matrix into one matrix, Table 3 show the aggregated decision matrix. All criteria are positive. Then apply steps of the neutrosophic VIKOR method to obtain the values of Z_a, U_a, R_a, then rank alternatives. Data security and privacy is the highest rank and Business continuity is the lowest rank by the VIKOR method. Table 4 show the values of Z_a, U_a, R_a and rank of alternatives. Fig. 3 shows the rank of alternatives.

Table 3. The aggregated decision matrix.

Criteria/Alternatives	COM_1	COM_2	COM_3	COM_4	COM_5	COM_6	COM_7	COM_8
$RCOM_1$	0.6999	0.8445	0.8722	0.6666	0.8722	0.8612	0.8445	0.8722
$RCOM_2$	0.2830	0.8167	0.9000	0.9000	0.6999	0.6388	0.3830	0.4609
$RCOM_3$	0.8722	0.6943	0.8445	0.5276	0.5220	0.8445	0.6666	0.5220
$RCOM_4$	0.4609	0.6666	0.6721	0.6388	0.3163	0.5553	0.9000	0.8445
$RCOM_5$	0.4942	0.8167	0.3497	0.6721	0.5943	0.2830	0.8167	0.8167
$RCOM_6$	0.2830	0.4887	0.8167	0.8722	0.5220	0.4277	0.9000	0.4887
$RCOM_7$	0.8167	0.5220	0.8722	0.6999	0.4887	0.5220	0.5610	0.8722
$RCOM_8$	0.6943	0.4609	0.7277	0.8167	0.5666	0.5220	0.5220	0.3887
$RCOM_9$	0.5000	0.6943	0.8445	0.8722	0.6943	0.9000	0.4766	0.9000
$RCOM_{10}$	0.4887	0.6333	0.5276	0.7277	0.6666	0.7277	0.8445	0.6943

Table 4. The values of Z_a, U_a, R_a and rank of alternatives.

Criteria/Alternatives	Z_a	U_a	R_a	$Rank$
$RCOM_1$	0.127915	0.051025	0	1
$RCOM_2$	0.552401	0.192184	0.972253	10
$RCOM_3$	0.357762	0.109915	0.464308	2

$RCOM_4$	0.514447	0.174461	0.86725	7
$RCOM_5$	0.539084	0.174461	0.894659	8
$RCOM_6$	0.559294	0.174461	0.917143	9
$RCOM_7$	0.478351	0.126017	0.655498	5
$RCOM_8$	0.577341	0.140514	0.816979	6
$RCOM_9$	0.368216	0.157403	0.644143	4
$RCOM_{10}$	0.400119	0.113567	0.524365	3

Then apply the neutrosophic MABAC method. Start with the Table 3. Then normalize the decision matrix and obtain the weighted normalized decision matrix, then obtain the border approximation area to attain the distance from the border approximation area in Table5, then obtain the total distance and rank alternatives according to the descending value of total distance in Table 6. According to Table 6 Data security and privacy is the highest rank and Provider lock-in is the lowest rank alternative. Fig. 4 shows the rank of alternatives.

Table 5. The distance from the border approximation area.

Criteria/Alternatives	COM_1	COM_2	COM_3	COM_4	COM_5	COM_6	COM_7	COM_8
$RCOM_1$	-0.801	-0.859	-0.875	-0.912	-0.752	-0.767	-0.755	-0.878
$RCOM_2$	-0.924	-0.865	-0.871	-0.874	-0.806	-0.830	-0.926	-0.927
$RCOM_3$	-0.750	-0.891	-0.879	-0.934	-0.862	-0.772	-0.821	-0.919
$RCOM_4$	-0.872	-0.897	-0.905	-0.916	-0.927	-0.854	-0.734	-0.881
$RCOM_5$	-0.862	-0.865	-0.953	-0.911	-0.839	-0.931	-0.765	-0.884
$RCOM_6$	-0.924	-0.935	-0.883	-0.878	-0.862	-0.890	-0.734	-0.923
$RCOM_7$	-0.766	-0.928	-0.875	-0.906	-0.872	-0.863	-0.860	-0.878
$RCOM_8$	-0.802	-0.941	-0.896	-0.887	-0.848	-0.863	-0.875	-0.935
$RCOM_9$	-0.860	-0.891	-0.879	-0.878	-0.808	-0.756	-0.892	-0.875
$RCOM_{10}$	-0.863	-0.904	-0.926	-0.902	-0.817	-0.805	-0.755	-0.899

Table 6. The values of Z_a, U_a, R_a and rank of alternatives.

Criteria/Alternatives	$Total\ Distance$	$Rank$
$RCOM_1$	0.127915	1
$RCOM_2$	0.552401	8
$RCOM_3$	0.357762	2
$RCOM_4$	0.514447	6
$RCOM_5$	0.539084	7
$RCOM_6$	0.559294	9
$RCOM_7$	0.478351	5
$RCOM_8$	0.577341	10

$RCOM_9$	0.368216	3
$RCOM_{10}$	0.400119	4

Fig 2. The ten alternatives are used in this study.

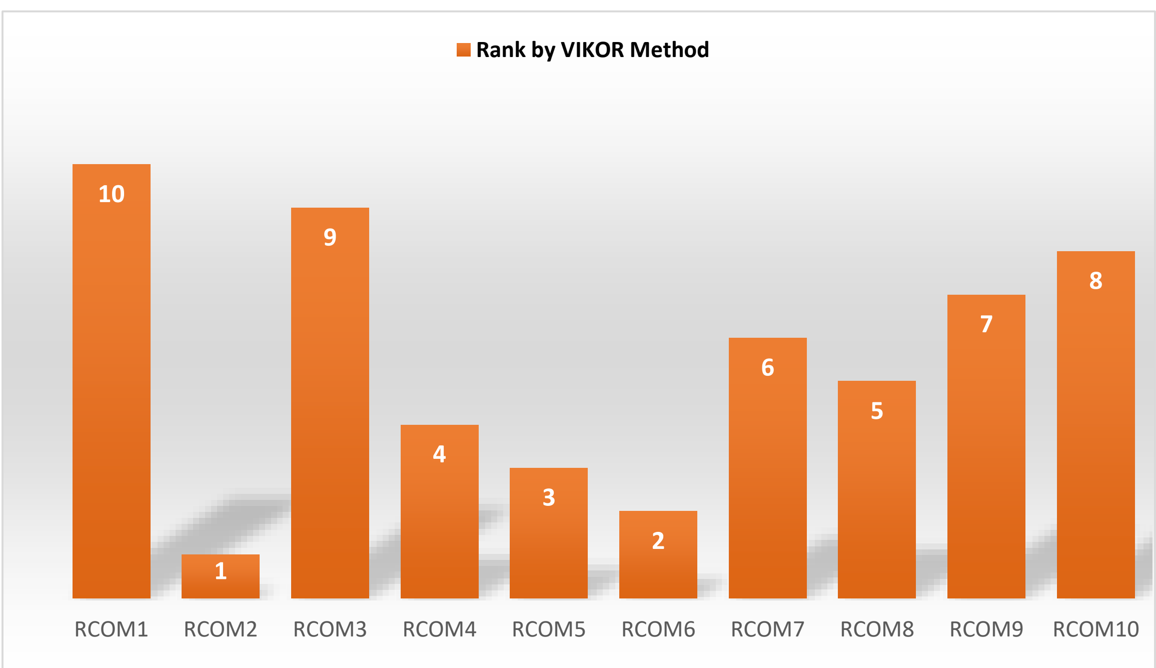

Fig 3. The rank of alternatives by the VIKOR method

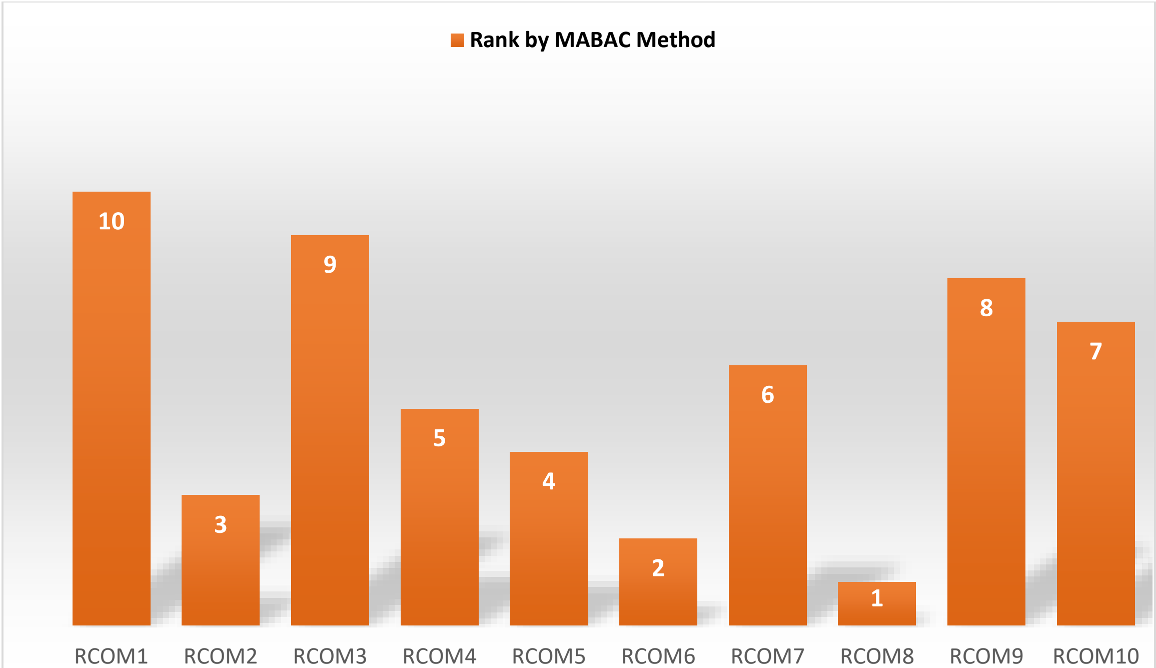

Fig 4. The rank of alternatives by the VIKOR method

5. Sensitivity Analysis

In this section, we would change the weights of criteria to show the robust of the model. When we change the weights of criteria, the rank of alternatives will change. In this section, we used five cases changes of weights of criteria. We applied these cases in the neutrosophic VIKOR and MABAC model and show the rank of alternatives. Table 7. Show the five cases. In the neutrosophic VIKOR method, case 1,2,4,5 is agreed in highest rank ($RCOM_1$), but in case 3 the height rank is $RCOM_3$. In the neutrosophic MABAC, all cases agreed ($RCOM_1$) is the highest rank. Table 8. Show the rank of alternatives after changing in weights of criteria.

Table 7. Five case changes of weights

	$\mathbf{COM_1}$	$\mathbf{COM_2}$	$\mathbf{COM_3}$	$\mathbf{COM_4}$	$\mathbf{COM_5}$	$\mathbf{COM_6}$	$\mathbf{COM_7}$	$\mathbf{COM_8}$
Case 1	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125
Case 2	0.0714	0.0714	0.0714	0.0714	0.0714	0.0714	0.5	0.0714
Case 3	0.5	0.0714	0.0714	0.0714	0.0714	0.0714	0.0714	0.0714
Case 4	0.0714	0.0714	0.0714	0.0714	0.5	0.0714	0.0714	0.0714
Case 5	0.0714	0.0714	0.0714	0.0714	0.0714	0.5	0.0714	0.0714

Table 8. Rank of alternatives based on five cases

VIKOR Case1	VIKOR Case 2	VIKOR Case 3	VIKOR Case 4	VIKOR Case 5	MABA C Case1	MABA C Case 2	MABA C Case 3	MABA C Case 4	MABA C Case 5
$RCOM_1$	$RCOM_1$	$RCOM_3$	$RCOM_1$	$RCOM_1$	$RCOM_1$	$RCOM_1$	$RCOM_1$	$RCOM_1$	$RCOM_1$
$RCOM_{10}$	$RCOM_{10}$	$RCOM_7$	$RCOM_9$	$RCOM_9$	$RCOM_9$	$RCOM_4$	$RCOM_3$	$RCOM_9$	$RCOM_9$
$RCOM_9$	$RCOM_4$	$RCOM_1$	$RCOM_2$	$RCOM_3$	$RCOM_3$	$RCOM_{10}$	$RCOM_7$	$RCOM_2$	$RCOM_3$
$RCOM_7$	$RCOM_6$	$RCOM_8$	$RCOM_{10}$	$RCOM_{10}$	$RCOM_{10}$	$RCOM_6$	$RCOM_9$	$RCOM_{10}$	$RCOM_{10}$
$RCOM_3$	$RCOM_5$	$RCOM_9$	$RCOM_5$	$RCOM_2$	$RCOM_7$	$RCOM_5$	$RCOM_8$	$RCOM_5$	$RCOM_2$
$RCOM_2$	$RCOM_3$	$RCOM_{10}$	$RCOM_3$	$RCOM_4$	$RCOM_2$	$RCOM_3$	$RCOM_{10}$	$RCOM_3$	$RCOM_7$
$RCOM_4$	$RCOM_7$	$RCOM_5$	$RCOM_8$	$RCOM_7$	$RCOM_4$	$RCOM_9$	$RCOM_5$	$RCOM_7$	$RCOM_4$
$RCOM_5$	$RCOM_9$	$RCOM_4$	$RCOM_6$	$RCOM_8$	$RCOM_5$	$RCOM_7$	$RCOM_4$	$RCOM_8$	$RCOM_8$
$RCOM_6$	$RCOM_8$	$RCOM_2$	$RCOM_7$	$RCOM_6$	$RCOM_6$	$RCOM_8$	$RCOM_2$	$RCOM_6$	$RCOM_6$
$RCOM_8$	$RCOM_2$	$RCOM_6$	$RCOM_4$	$RCOM_5$	$RCOM_8$	$RCOM_2$	$RCOM_6$	$RCOM_4$	$RCOM_5$

6. Comparative Analysis

In this section, we made a comparison with the neutrosophic TOPSIS method to show the robust of this model. We use this data to apply with the TOPSIS method. After applying this comparison, we found that the heights rank is constant in two method. Table 9. Show the comparison between VIKOR, MABAC and TOPSIS methods.

Table 9. Rank of alternatives based on comparative analysis.

MABAC	TOPSIS	VIKOR
$RCOM_1$	$RCOM_1$	$RCOM_1$
$RCOM_3$	$RCOM_3$	$RCOM_3$
$RCOM_9$	$RCOM_{10}$	$RCOM_{10}$
$RCOM_{10}$	$RCOM_9$	$RCOM_9$
$RCOM_7$	$RCOM_7$	$RCOM_7$
$RCOM_4$	$RCOM_8$	$RCOM_8$
$RCOM_5$	$RCOM_4$	$RCOM_4$
$RCOM_2$	$RCOM_5$	$RCOM_5$
$RCOM_6$	$RCOM_2$	$RCOM_6$
$RCOM_8$	$RCOM_6$	$RCOM_2$

7. Managerial Implications

Cloud computing surround many risks. That effect on market, companies, good and other. So, these risks should be identified and ranked. The hybrid model introduced by this study to identify and rank alternatives. The hybrid model contains the VIKOR and MABAC methods. This study provides the rank of risks of cloud computing.

8. Conclusions and Future work

Risks associated with cloud computing might limit a company's exploration efforts, such as entering a new market, generating new goods and services, locating new clients, and absorbing new information. Furthermore, cloud computing hazards might obstruct a company's exploitation operations, which include competing in the present market with current customers, current goods, and current expertise. In this study, we used eight criteria and ten alternatives. The SVN is used to obtain the rank of alternatives. The neutrosophic set is hybrid with the VIKOR and MABAC methods to obtain the weights of criteria and rank of risks. In future work, we suggest this model be used with other problems like energy selection and others and can use other MCDM methods such as TOPSIS, AHP, and others.

Conflict of interest: Authors declare that there is no conflict of interest about the research.

Funding: This research has no funding source.

Ethical approval: None of the authors' experimented with human subjects or animals during this research.

References

[1] Q. Zheng, D. Gu, C. Liang, and Y. Fang, "Impact of a firm's physical and knowledge capital intensities on its selection of a cloud computing deployment model," *Inf. Manag.*, vol. 57, no. 7, p. 103259, 2020.

[2] G. Garrison, R. L. Wakefield, and S. Kim, "The effects of IT capabilities and delivery model on cloud computing success and firm performance for cloud supported processes and operations," *Int. J. Inf. Manage.*, vol. 35, no. 4, pp. 377–393, 2015.

[3] O. Ali and V. Osmanaj, "The role of government regulations in the adoption of cloud computing: A case study of local government," *Comput. law Secur. Rev.*, vol. 36, p. 105396, 2020.

[4] N. Subramanian and A. Jeyaraj, "Recent security challenges in cloud computing," *Comput. Electr. Eng.*, vol. 71, pp. 28–42, 2018.

[5] A. K. Kar and A. Rakshit, "Flexible pricing models for cloud computing based on group decision making under consensus," *Glob. J. Flex. Syst. Manag.*, vol. 16, no. 2, pp. 191–204, 2015.

[6] S. Evans and H. Bahrami, "Super-flexibility in practice: Insights from a crisis," *Glob. J. Flex. Syst. Manag.*, vol. 21, no. 3, pp. 207–214, 2020.

[7] T. Vasiljeva, S. Shaikhulina, and K. Kreslins, "Cloud computing: Business perspectives, benefits and challenges for small and medium enterprises (case of Latvia)," *Procedia Eng.*, vol. 178, pp. 443–451, 2017.

[8] M. Stieninger and D. Nedbal, "Characteristics of cloud computing in the business context: A systematic literature review," *Glob. J. Flex. Syst. Manag.*, vol. 15, no. 1, pp. 59–68, 2014.

[9] L. I. U. Peiyu and L. I. U. Dong, "The new risk assessment model for information system in cloud

computing environment," *Procedia Eng.*, vol. 15, pp. 3200–3204, 2011.

[10] D. C. Chou, "Cloud computing risk and audit issues," *Comput. Stand. Interfaces*, vol. 42, pp. 137–142, 2015.

[11] S. Paquette, P. T. Jaeger, and S. C. Wilson, "Identifying the security risks associated with governmental use of cloud computing," *Gov. Inf. Q.*, vol. 27, no. 3, pp. 245–253, 2010.

[12] W. Westera, "How people learn while playing serious games: A computational modelling approach," *J. Comput. Sci.*, vol. 18, pp. 32–45, 2017.

[13] M. J. Baucas and P. Spachos, "Using cloud and fog computing for large scale IoT-based urban sound classification," *Simul. Model. Pract. theory*, vol. 101, p. 102013, 2020.

[14] A. Ali, D. Warren, and L. Mathiassen, "Cloud-based business services innovation: A risk management model," *Int. J. Inf. Manage.*, vol. 37, no. 6, pp. 639–649, 2017.

[15] T. B. Oluwafemi, S. Mitchelmore, and K. Nikolopoulos, "Leading innovation: Empirical evidence for ambidextrous leadership from UK high-tech SMEs," *J. Bus. Res.*, vol. 119, pp. 195–208, 2020.

[16] C. A. O'Reilly III and M. L. Tushman, "Ambidexterity as a dynamic capability: Resolving the innovator's dilemma," *Res. Organ. Behav.*, vol. 28, pp. 185–206, 2008.

[17] B.-H. Lee, E. K. Dewi, and M. F. Wajdi, "Data security in cloud computing using AES under HEROKU cloud," in *2018 27th wireless and optical communication conference (WOCC)*, 2018, pp. 1–5.

[18] S. U. Lee, G. Park, and J. Kang, "The double-edged effects of the corporate venture capital unit's structural autonomy on corporate investors' explorative and exploitative innovation," *J. Bus. Res.*, vol. 88, pp. 141–149, 2018.

[19] Y. Wang, Y. Chen, N. Wang, S. Nevo, G. Kou, and F. E. Alsaadi, "Impact of the strategic role of IT on explorative and exploitative innovation activities: The role of environmental uncertainty," *Decis. Sci.*, vol. 51, no. 3, pp. 542–574, 2020.

[20] M. Ghasemaghaei and G. Calic, "Does big data enhance firm innovation competency? The mediating role of data-driven insights," *J. Bus. Res.*, vol. 104, pp. 69–84, 2019.

[21] R. Rialti, L. Zollo, A. Ferraris, and I. Alon, "Big data analytics capabilities and performance: Evidence from a moderated multi-mediation model," *Technol. Forecast. Soc. Change*, vol. 149, p. 119781, 2019.

[22] D. A. Battleson, B. C. West, J. Kim, B. Ramesh, and P. S. Robinson, "Achieving dynamic capabilities with cloud computing: An empirical investigation," *Eur. J. Inf. Syst.*, vol. 25, no. 3, pp. 209–230, 2016.

[23] E. Severgnini, A. R. W. Takahashi, and G. Abib, "Risk and Organizational ambidexterity: a meta-synthesis of a case study and a framework," *BBR. Brazilian Bus. Rev.*, vol. 16, pp. 470–499, 2019.

[24] A. Tchernykh, U. Schwiegelsohn, E. Talbi, and M. Babenko, "Towards understanding uncertainty in cloud computing with risks of confidentiality, integrity, and availability," *J. Comput. Sci.*, vol. 36, p. 100581, 2019.

[25] A. Bhardwaj and S. Goundar, "A framework to define the relationship between cyber security and cloud performance," *Comput. Fraud Secur.*, vol. 2019, no. 2, pp. 12–19, 2019.

[26] J. Benitez, A. Castillo, J. Llorens, and J. Braojos, "IT-enabled knowledge ambidexterity and innovation performance in small US firms: The moderator role of social media capability," *Inf. Manag.*, vol. 55, no. 1, pp. 131–143, 2018.

[27] R. Montealegre, K. Iyengar, and J. Sweeney, "Understanding ambidexterity: Managing contradictory tensions between exploration and exploitation in the evolution of digital infrastructure," *J. Assoc. Inf. Syst.*, vol. 20, no. 5, p. 1, 2019.

[28] C. M. Mariana, "Secure Computing Benefits, Risk and Controls," *IEEE-Information Secur. Soutch Africa*, 2011.

[29] A. Bisong and M. Rahman, "An overview of the security concerns in enterprise cloud computing," *arXiv Prepr. arXiv1101.5613*, 2011.

[30] C. Yang, Q. Huang, Z. Li, K. Liu, and F. Hu, "Big Data and cloud computing: innovation opportunities and challenges," *Int. J. Digit. Earth*, vol. 10, no. 1, pp. 13–53, 2017.

[31] E. Loukis, N. Kyriakou, K. Pazalos, and S. Popa, "Inter-organizational innovation and cloud computing," *Electron. Commer. Res.*, vol. 17, no. 3, pp. 379–401, 2017.

[32] M. Abdel-Baset, V. Chang, A. Gamal, and F. Smarandache, "An integrated neutrosophic ANP and VIKOR method for achieving sustainable supplier selection: A case study in importing field," *Comput. Ind.*, vol. 106, pp. 94–110, 2019.

[33] M. Abdel-Basset, Y. Zhou, M. Mohamed, and V. Chang, "A group decision making framework based on neutrosophic VIKOR approach for e-government website evaluation," *J. Intell. Fuzzy Syst.*, vol. 34, no. 6, pp. 4213–4224, 2018.

[34] X. Peng and J. Dai, "Approaches to single-valued neutrosophic MADM based on MABAC, TOPSIS and new similarity measure with score function," *Neural Comput. Appl.*, vol. 29, no. 10, pp. 939–954, 2018.

[35] D. Pamučar and D. Božanić, *Selection of a location for the development of multimodal logistics center: Application of single-valued neutrosophic MABAC model*. Infinite Study, 2019.

[36] Y.-H. Huang, G.-W. Wei, and C. Wei, "VIKOR method for interval neutrosophic multiple attribute group decision-making," *Information*, vol. 8, no. 4, p. 144, 2017.

[37] H. Eroğlu and R. Şahin, "A neutrosophic VIKOR method-based decision-making with an improved distance measure and score function: case study of selection for renewable energy alternatives," *Cognit. Comput.*, vol. 12, no. 6, pp. 1338–1355, 2020.

[38] X. Peng and J. Dai, "Algorithms for interval neutrosophic multiple attribute decision-making based on MABAC, similarity measure, and EDAS," *Int. J. Uncertain. Quantif.*, vol. 7, no. 5, 2017.

[39] P. Ji, H. Zhang, and J. Wang, "Selecting an outsourcing provider based on the combined MABAC–ELECTRE method using single-valued neutrosophic linguistic sets," *Comput. Ind. Eng.*, vol. 120, pp. 429–441, 2018.

[40] A. Dutta, G. C. A. Peng, and A. Choudhary, "Risks in enterprise cloud computing: the perspective of IT experts," *J. Comput. Inf. Syst.*, vol. 53, no. 4, pp. 39–48, 2013.

[41] A. Elzamly and B. Hussin, "Classification of critical cloud computing security issues for banking organizations: A cloud Delphi study," *Int. J. Grid Distrib. Comput.*, vol. 9, no. 8, pp. 137–158, 2016.

[42] O. Boutkhoum, M. Hanine, T. Agouti, and A. Tikniouine, "Selection problem of cloud solution for big data accessing: Fuzzy AHP-PROMETHEE as a proposed methodology.," *J. Digit. Inf. Manag.*, vol. 14, no. 6, 2016.

[43] O. Boutkhoum, M. Hanine, T. Agouti, and A. Tikniouine, "A decision-making approach based on fuzzy AHP-TOPSIS methodology for selecting the appropriate cloud solution to manage big data projects," *Int. J. Syst. Assur. Eng. Manag.*, vol. 8, no. 2, pp. 1237–1253, 2017.

[44] A. Amini, N. Jamil, A. R. Ahmad, and H. Sulaiman, "A fuzzy logic based risk assessment approach for evaluating and prioritizing risks in cloud computing environment," in *International Conference of Reliable Information and Communication Technology*, 2017, pp. 650–659.

[45] A. P. H. de Gusmão, M. M. Silva, T. Poleto, L. C. e Silva, and A. P. C. S. Costa, "Cybersecurity risk analysis model using fault tree analysis and fuzzy decision theory," *Int. J. Inf. Manage.*, vol. 43, pp. 248–260, 2018.

[46] K. Patel and A. Alabisi, "Cloud computing security risks: Identification and assessment," *J. New Bus. Ideas Trends*, vol. 17, no. 2, pp. 11–19, 2019.

[47] S. Krishnaveni and S. Prabakaran, "Ensemble approach for network threat detection and classification on cloud computing," *Concurr. Comput. Pract. Exp.*, vol. 33, no. 3, p. e5272, 2021.

[48] M. Swathy Akshaya and G. Padmavathi, "Taxonomy of security attacks and risk assessment of cloud computing," in *Advances in big data and cloud computing*, Springer, 2019, pp. 37–59.

[49] M. Jouini, L. Ben Arfa Rabai, and R. Khedri, "A quantitative assessment of security risks based on a multifaceted classification approach," *Int. J. Inf. Secur.*, vol. 20, no. 4, pp. 493–510, 2021.

[50] B. Sheehan, F. Murphy, A. N. Kia, and R. Kiely, "A quantitative bow-tie cyber risk classification and assessment framework," *J. Risk Res.*, vol. 24, no. 12, pp. 1619–1638, 2021.

[51] M. T. Taghavifard and S. Majidian, "Identifying Cloud Computing Risks based on Firm's Ambidexterity Performance using Fuzzy VIKOR Technique," *Glob. J. Flex. Syst. Manag.*, vol. 23, no. 1, pp. 113–133, 2022.

[52] Y. Subas, "Neutrosophic numbers and their application to Multi-attribute decision making problems (In Turkish)(Master's Thesis, Kilis 7 Aralık University, Graduate School of Natural and Applied Science),(2015)," *Neutrosophic Sets Syst.*, vol. 19, p. 141, 2018.

[53] I. Deli and Y. Şubaş, "A ranking method of single valued neutrosophic numbers and its applications to multi-attribute decision making problems," *Int. J. Mach. Learn. Cybern.*, vol. 8, no. 4, pp. 1309–1322, 2017.

[54] M. Abdel-Basset, A. Gamal, N. Moustafa, A. Abdel-Monem, and N. El-Saber, "A Security-by-Design Decision-Making Model for Risk Management in Autonomous Vehicles," *IEEE Access*, 2021.

Received: Nov 20, 2021. Accepted: Feb 2, 2022