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An evaluation framework for selecting cloud service provider in neutrosophic environment and Modified Generative Adversarial Network

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Abstract

For many businesses, cloud computing is essential to their development. Any business that moves its work to the cloud faces the major challenge of choosing the best cloud service provider among the variety of options available, each with unique advantages and benefits. In the case where values are absent from the evaluation of options, the novel framework presented in this study can be used to choose the best provider. The framework is separated into two sections, with the first section focusing on the Modified Generative Adversarial Network (M-GAN) for data imputation of missing data. With the modifications, GAN now has an accuracy of almost 0.91. The second step is the multi-criteria decision-making neutrosophic algorithm for selecting the most suitable provider according to different eight criteria (Availability, Throughput, Successibility, Reliability, Latency, Response time, Response Time of Customer Services, and Cost). According to the experiments done in the paper, the Novel framework has achieved success in choosing suitable providers. It was found that the proposed model obtained accuracy of 91% in 0.05 computation time for 1000 providers.

Keywords: Cloud service provider, neutrosophic, GAN, deep learning.

1. Introduction

One of the most important technologies available to a variety of organisations is cloud computing. With the use of cloud computing, businesses may access the most essential services online without having to physically install them. Any organization's major challenge is selecting an appropriate provider based on the available options and business requirements [1-3]. In the case that data is missing for a variety of reasons, choosing a suitable provider process among the available cloud services remains a challenging task for any organisation and stockholder. The following is a summary of the processes made in the proposed framework:

1- Multiple criteria: There are many various requirements and criteria for organizations. For instance, because every organization has varied needs, some organizations must reduce taxes while others must spend a lot of money to improve availability and security.

2- Missing values of evaluations: The shortage and the missing values for each criteria can affect the final decision of selecting a suitable provider, so the imputation of the missing value can be one of the most important tasks for the stack holder before the decision-making process.

3-Opinions of experts: The final decision-making process for selecting the provider among the various providers might be positively or negatively impacted by the opinions of experts.

The main goal of the proposed framework in this paper is to select the best provider out of those that are accessible in order to best meet the needs of the organization, particularly when there are data shortages that prevent accurate evaluation of each criteria. The framework divides the work into two stages: the first stage addresses how to handle missing evaluation criteria using a modified version of Generative Adversarial Network (M-GAN) [28–30], and the second stage discusses using multi-criteria decision-making based on a neutrosophic algorithm to select the best provider based on organizational needs and requirements.

Each stockholder faces a challenging and complicated problem when selecting reliable providers when there are missing data. For a variety of reasons, including the fact that it was never collected or records were missed, data may be missing or lost. To generate missing or lost values, one can apply the GAN deep learning framework. The GAN is composed of two parts: the generator, which generates the missing data, and the discriminator, which separates between the generator-generated data and the available data. The generator is trained to increase the misclassification rate of the discriminator, while the discriminator is trained to minimize classification loss. By evaluating the alternatives with regard to the weights of the criteria, which may vary from one organization to another depending on their priorities, multi-criteria decision-making based on a neutrosophic algorithm is used to choose the best suitable provider according to the organization's needs and requirements [4–9]. Some businesses prioritize cost over response time, others prioritize availability; and still others prioritize reaction time. With varying objectives and interests, each of these enterprises will discover their needs in this framework, which will enable them to select the finest cloud service provider for their particular requirements. The following is a summary of the contributions made by this paper:

1- The novel framework uses a modified GAN to handle various types of data with missing values.

2- The Framework used a multi-criteria decision-making algorithm based on neutrosophic theories and achieved in choosing the best suitable provider while respecting the degree of intermediacy in neutrosophic sets.

3- In the case that there are incompatible criteria, different interests among the decision-makers, or concerns with accuracy, the suggested framework can select the appropriate provider.

The remainder of this paper is structured as follows: The rest of this paper is organized as follows: Section 2 introduces the related works and the main findings of the previous research. Section 3 introduces the methodology and describes the main stages in the proposed framework. Section 4 demonstrates the discussion and experimental results. Section 5 is the paper’s conclusion.

2. Related Works

Neutrosophic set theory has grown in significance in many decision-making situations because it gives decision-makers the freedom to evaluate the options in language terms. It has been incorporated with several Multi-Criteria Decision-Making (MCDM) techniques and aids decision-makers in resolving any uncertainty in their judgement. It is initially important to establish the standards for calculating and choosing the best cloud services. Numerous studies have identified the important parameters for evaluating the performance of cloud services [4-17].

In [1], Liu et al employed DEMATEL, a decision-making, trial, and evaluation laboratory method, to solve the challenge of choosing a transportation service provider. The language ratings of experts were converted to neutrosophic values using a neutrosophic set, and DEMATEL was used to rank the transport service providers.

In [2], Abdel-Basset et al.combined DEMATEL and neutrosophic set theory to study the supply chain management supplier selection criteria. Expert judgement was adjusted using the neutrosophic set, and the most important factors affecting supply chain management were discovered using DEMATEL.

In [3], Karasan et al. used a combined distance-based assessment (CODAS) and an integrated neutrosophic set were used to locate the wind energy plant. While using CODAS to determine the ideal location for a wind farm, they used interval value neutrosophic set to deal with the uncertainty.

In [4], Abdel-Basset et al. identified SWOT analysis as a strategic planning tool that uses extended AHP with the neutrosophic set to identify strengths, weaknesses, opportunities, and threats.

In [5], Abdel-Basset et al. have additionally expanded ANP and TOPSIS for the supplier selection problem using neutrosophic set theory. We may therefore conclude from the foregoing considerations that the neutrosophic set has been merged with a variety of MCDM techniques to address a variety of selection difficulties.One of the main obstacles for cloud consumers in the realm of cloud computing is choosing a cloud service. Methods for choosing cloud services have been put out by a number of authors.

In [6], Garg et al. created the SMICloud framework, which uses the AHP approach to rate cloud services. To calculate the various functional and non-functional SMI framework QoS characteristics, they developed equations. AHP is used to determine each QoS metric's priority when choosing which cloud services to use. The cloud services were ranked using the priority vector that was created by aggregating all QoS indicators.

In [7], Sidhu and Singh assigned that to locate a reliable cloud service, a new trust evaluation framework was created utilising AHP and TOPSIS. Each QoS parameter's significance is determined based on the subjective evaluations of each QoS made by cloud users using AHP. Based on service quality and weight determined by AHP, the TOPSIS was utilised to identify the best cloud service.

In [8], Kumar et al. developed a flexible framework for choosing cloud services for a fuzzy environment that allows users and cloud experts to express their opinions linguistically. They chose a cloud service using fuzzy TOPSIS and AHP. To handle fuzziness and rank cloud services, TOPSIS was merged with a triangular fuzzy number, and the weight of the QoS criteria was calculated using AHP.

In [9], Jatoth et al used AHP and Grey TOPSIS to develop a framework for service selection. They combined Grey set theory with TOPSIS to rank the cloud services and used AHP to determine the relevance of QoS metrics.

In [10], Lee and Seo built a system to locate the best IaaS cloud service in a hazy setting. They employed the fuzzy Delphy approach to locate the most crucial QoS parameters from each aspect and the balanced scorecard to identify the key QoS metrics from areas like finance, business process, etc. The priority vector of each QoS parameter was then computed using AHP with triangular fuzzy numbers in order to rank the cloud services.

In [31], Radulescu et al. created a ranking system for cloud services utilizing the improved TOPSIS method and entropy. The weights of the QoS parameter were determined using the entropy method. They altered the standard TOPSIS by replacing the Equilidean distance with the Minkowski distance in order to select the best cloud service provider.

In [32], Basu and Ghosh built a rank reversal robust framework using fuzzy TOPSIS to rate cloud services in a fuzzy context. However, it cannot handle measurements for interdependent QoS.

In [33], Jatoth et al. used AHP and Grey TOPSIS to develop a framework for service selection. They combined Grey set theory with TOPSIS to rank the cloud services and used AHP to determine the relevance of QoS metrics.

The previous discussions demonstrate that selecting a cloud service provider is a decision-making problem, and most writers used MCDM techniques to determine the best cloud service providers. However, neutrosophic settings do not benefit from the frameworks for selecting cloud services that have been researched in the literature. Neutosophic set theory has lately gained importance as a way to more effectively handle the problem of uncertainty. So, in order to rank the cloud services, we have combined neutrosophic set theory for the first time. The new method effectively and solidly rates cloud services in the neutrosophic environment. This work, in our opinion, is the first to evaluate cloud services by use of a modified GAN and neutrosophic set theory.

Prior research has concentrated on a single point of view, MCDM with uniform and understandable datasets. We want to achieve better results than past studies, so we're going to concentrate on handling missing data by applying modified GAN [28–30] in our study.

3. Methodology

This section outlines the processes that were taken to construct the framework that would be used to select the best cloud service provider. They are as follows:

Step 1**:** Data Collection: Identify the Alternatives and Available Cloud service providers.

Step 2: Use a modified GAN to fill in the missing information.

Step 3: Utilize a multi-criteria decision-making method based on neutrosophic to select the most appropriate cloud service provider from the list of options.

3.1 Cloud service provider Dataset

The dataset gathered to describe various cloud service providers is just what the framework uses to make decisions. The dataset was compiled from the Cloud Harmony Network-Testing Website and contained the Quality of Service (QoS) performance of 80 cloud computing providers [34]. The dataset also makes use of several characteristics, including throughput, availability, and successability, to evaluate various servers. There are about 1200 rows in the dataset. The dataset's missing values, which require imputation, are the main issue. In order to impute missing values for a particular case study in the following section, the paper uses a modified version of GAN.

3.2 Imputation Missing Values Stage

GAN is a deep learning model that consists of two parts: the generator, which generates the missing data during the imputation process, and the discriminator, which determines how to fill in the blanks. This component is used to distinguish between actual, original data and data generated by the generator component. The framework consists of five phases and employs a modified version of GAN called M-GAN modified in [35].

3.3 Multi-criteria Selection Method Based on Neutrosophic

3.3.1 Preliminaries related to a neutrosophic set

Definition 1.

In the Neutrosophic set, the degree of indeterminacy (I) was first introduced as an independent component by the neutrosophic set [24].

The following describes the truth value for the neutrosophic set: Consider the set N, which is defined as follows: $\boldsymbol{N} = \{(\boldsymbol{T}, \boldsymbol{I}, \boldsymbol{F}) : \boldsymbol{T}, \boldsymbol{I}, \boldsymbol{F} \subseteq [\mathbf{0}, \mathbf{1}]\}$, a neutrosophic valuation. n is a mapping from the set of propositional formulae to N, meaning that for each sentence x, we have the formula

$$A(x) = (T, I, F). A = \{\langle x, T_A(x), I_A(x), F_A(x)\rangle | x \epsilon X\} \tag{1}$$

Definition 2.

Single Valued Neutrosophic Set (SVNS) was developed to facilitate real world applications neutrosophic set and set-theoretic operators. A single-valued neutrosophic set is a special case of a neutrosophic set proposed as a generalization of intuitionistic fuzzy sets in order to deal with incomplete information [25].

A single value neutrosophic set A is denoted by

$$A = \{\langle x, T_A(x), I_A(x), F_A(x)\rangle | x \epsilon X\} \tag{2}$$

Definition 3.

Single-valued neutrosophic numbers (SVN numbers) are represented by the symbol $A = (a, b, c)$, where $a, b, c \in [0,1]$ and $a+b+c \leqslant 3$. Sometimes, while solving problems in the real world, we can represent some qualitative information by using linguistic phrases like "good" or "bad" rather than numbers. Many traditional multi-criteria decision-making methods have been modified for neutrosophic problems [26].

Let $A = \{\langle x, T_A(x), I_A(x), F_A(x)\rangle | x \epsilon X\}$ and $B = \{\langle x, T_B(x), I_B(x), F_B(x)\rangle | x \epsilon X\}$ be two single value neutrosophic set, the following operations are defined as:

$$A \oplus B = \langle T_A(x) + T_B(x) - T_A(x)T_B(x), I_A(x)I_B(x), F_A(x)F_B(x)\rangle \tag{3}$$

$$A \otimes B = \langle T_A(x)T_B(x), I_A(x) + I_B(x) - I_A(x)I_B(x), F_A(x) + F_B(x) - F_A(x)F_B(x)\rangle \tag{4}$$

3.3.2. Construction of Neutrosophic Sets

Step 1: Identify the linguistic terms and their neutrosophic sets.

Experts should identify the linguistic phrases that will be used to evaluate the alternatives and then specify the neutrosophic set value for each linguistic term. These linguistic expressions will be used in all following evaluation procedures.

Step 2: Create a Choice Rule (CR) with neutrosophic set.

Permit experts to examine the linguistic opinions of each option in order to evaluate each criterion by contrasting the criterion and alternatives using the linguistic terms they had previously identified. The linguistic term will be transformed into a neutrosophic set value using the mapping function after the choice rule has been computed.

Step 3: Identify the Scores (S) for each criteria

The experts will offer linguistic opinions for each need based on linguistic expressions they have previously identified. The linguistic phrases provided by the expert for each criterion are converted into the neutrosophic set using a suitable mapping function.

Step 4: Calculate the Scored Choice Rule (SCR).

Multiplying CR with scores results in the computation of the SCR in the neutrosophic set.

$$C^S = C \otimes S \tag{5}$$

Step 5: Calculate the Positive Neutrosophic Set (PNS) and Negative Neutrosophic Set (NNS)

The two types of criteria that can be utilized to select the best alternative are benefit and cost criteria. Cost criteria should have the least value possible, whereas benefit criteria should have the highest value possible according to experts. The PNS and NNS were developed with cost and benefit considerations in mind. PNS and NNS, respectively, are the best and worst alternatives. Equations (6,7) are used to calculate the PNS and NNS, respectively.

$$V^+ = PNS = [\langle T_1^+, I_1^+, F_1^+\rangle \quad \langle T_2^+, I_2^+, F_2^+\rangle \quad \cdots \langle T_3^+, I_3^+, F_3^+\rangle\ ] \tag{6}$$

$$V^- = NNS = [\langle T_1^-, I_1^-, F_1^-\rangle \quad \langle T_2^-, I_2^-, F_2^-\rangle \quad \cdots \langle T_3^-, I_3^-, F_3^-\rangle\ ] \tag{7}$$

Step 6: Calculate the Grades for each alternative using the PNS and NNS.
Use PNS (V+) and NNS (V-) to determine the grade for each option. Equations (8,9), respectively, show the grades measurement that was used to determine the grades between alternative Vi from V+ and V-.

$$G_i^+ = C^S.V^+ = \sum_{j=1}^{n} T_{C^S}.T_{V^+} + I_{C^S}.I_{V^+} + F_{C^S}.F_{V^+} \quad (8)$$

$$G_i^- = C^S.V^- = \sum_{j=1}^{n} T_{C^S}.T_{V^-} + I_{C^S}.I_{V^-} + F_{C^S}.F_{V^-} \quad (9)$$

Step 7: Calculate the Stability of each alternative.
The stability of each alternative is calculated using Equation (10). The stability demonstrates how similar the alternative is to PNS (V+) and NNS (V-).

$$S_i = \frac{G_i^-}{G_i^- + G_i^+} \quad (10)$$

Where S_i represents the closeness index of alternative i. The alternatives are ranked according to the proximity index of each.

Step 8: Rank the alternatives.
The alternatives are ranked using the proximity index, with the alternative with the highest value receiving the best ranking and the alternative with the lowest receiving the worst.

3.3.3 Building Neutrosophic Algorithm

First, experts have unique linguistic needs based on the features of each cloud service provider. Logical decision-making is used in conjunction with the neutrosophic set to lessen subjective unpredictability. Because it's likely that some of the values are missing, a modified GAN technique is used to find the values. The scores of each linguistic value (CR) and attribute are then continuously determined by identifying uncertainty and using the incomplete information given by the selection committee. The links between the attributes are used to assemble the preferences of the CR. In contrast to earlier approaches, the scores of the CRs are computed logically and used for aggregation in this paradigm. The Neutrosophic Method is then enlarged, and the scores of the qualities and choice rule are utilized to determine the cloud service providers' top priority. The framework is subjected to two assessments: one that contrasts it with current practices and the other that does a knowledge evaluation of various techniques to help explain its advantages and disadvantages. The proposed Neutrosophic Algorithm's pseudocode is shown in Algorithm 1.

Algorithm 1 Pseudo-code of Neutrosophic Algorithm

Input: n: number of Cloud Service Providers, m: number of Criteria Parameters
Output: Rank of Cloud Service Providers
1: Input Linguistics terms and their neutrosophic set by experts
2: Input CR and Scores of each criteria in Linguistic Term
3: Convert CR and Scores of each QoS into Neutrosophic CR and neutrosophic Scores using Eq. (5).
4: for each $\langle \boldsymbol{T}(\boldsymbol{x}_{i,j}), \boldsymbol{I}_A(\boldsymbol{x}_{i,j}), \boldsymbol{F}_V(\boldsymbol{x}_{i,j})\rangle$ in CR use Eq. (4).
end for
5: Compute PNS and NNS with respect to the CRs using Eqs. (6) and (7).
6: Calculate the Score of each alternative from PNS and NNS
7: for i=1 do
start for
$\boldsymbol{S}_i^+ = \boldsymbol{D}^W.\boldsymbol{V}^+$
$\boldsymbol{S}_i^- = \boldsymbol{D}^W.\boldsymbol{V}^-$
end for
8 Calculate the Stability of each alternative using Eq. (10).
9: for i=1 do
start for
$\boldsymbol{C}_i = \frac{\boldsymbol{S}_i^-}{\boldsymbol{S}_i^- + \boldsymbol{S}_i^+}$
end for
10: Rank the cloud service providers in descending order of $\boldsymbol{C}_i$

4. Results and discussion

4.1 Cloud Service Providers under Study

The case study in this paper uses five cloud service providers: AmazonHistoricalPricing, GoogleSearchService, ClientService, Conversor, and AreaService and eight different criteria [34].

4.1.1 *Criteria Selection*

The first step in the case study of selecting the best suitable cloud service provider is identifying the criteria which have been used to asses each cloud service provider.

4.1.2 *Cloud service provider Assessment*

The methodology's second step is cloud service provider identification. The methodology employs the data from the modified GAN after imputation in this stage. The first column of Table 1 refers to the names of the case study's cloud service providers, and row 1 relates to the case study's criteria.

Table 1. cloud service providers table and criteria

Cloud service provider	Availability (%)	Throughput (invokes/sec)	Successability %	Reliability %
AmazonHistoricalPricing	81	19	82	73
GoogleSearchService	100	11	100	73
ClientService	93	4	98	73
Conversor	77	5	78	73
AreaService	83	29	84	73
Cloud service provider	**Latency (ms)**	**Response Time (ms)**	**Rscs(ms)**	**Cost ($)**
AmazonHistoricalPricing	5	56	86	15
GoogleSearchService	7	113	53	48
ClientService	27	143	65	37
Conversor	105	511	98	13
AreaService	3	107	115	15

4.1.3 *Linguistics Terms*

According to the judgments of experts, this section defines each linguistic term and the neutrosophic set. Table 2 shows the mapping between the neutrosophic set and language terms.

Table 2. Linguistics terms and neutrosophic set

Linguistic	Term	Neutrosophic Set
Absolutely Good	AG	<0.96,0.01,0.96>
Very Good	VG	<0.88,0.60,0.90>
Good	G	<0.78,0.65,0.54>
Medium-Good	MG	<0.73,0.60,0.80>
Average	AV	<0.50,0.50,0.50>
Medium-Bad	MB	<0.58,0.70,0.77>
Bad	B	<0.68,0.80,0.85>
Very Bad	VB	<0.60,0.90,0.90>
Absolutely Bad	AB	<0.01,0.96,0.96>

4.1.4 *Creation of CR*

In accordance with the linguistic terms, it defined in Table 2, the cloud specialists apply their expertise to create the CR. Table 3 shows the CR determined by the linguistic assessments of experts for five cloud service providers and eight criteria.

Table 3. CR with linguistics term

Cloud service provider	Availability	Throughput	Successability	Reliability
AmazonHistoricalPricing	AG	AB	VG	VB
GoogleSearchService	MB	AB	VB	B
ClientService	VG	AG	VG	G
Conversor	VB	AB	AV	MG
AreaService	AV	MB	B	VB

Cloud service provider	Latency	Response Time	RSCS	Cost
AmazonHistoricalPricing	G	B	MG	AV
GoogleSearchService	MB	AV	G	MG
ClientService	MG	AV	MB	B
Conversor	G	VG	AG	AB
AreaService	AB	G	AG	AB

4.1.5 *Determination of criteria scores*

Cloud users rate the significance of each of the eight criteria in accordance with their personal preferences, their organization's requirements, or the recommendations of cloud experts. Table 4 displays the weights assigned to each criterion by the cloud user.

Table 4. scores of criteria

Criteria	Availability	Throughput	Successability	Reliability
Weight	<0.96,0.01,0.96>	<0.01,0.96,0.96>	<0.88,0.60,0.90>	<0.60,0.90,0.90>

Criteria	Latency	Response Time	RSCS	Cost
Weight	<0.78,0.65,0.54>	<0.68,0.80,0.85>	<0.73,0.60,0.80>	<0.50,0.50,0.50>

4.1.6 *Conversion of CR and scores of criteria to neutrosophic sets*

This section discusses how to translate CR and criterion scores into neutrosophic CR and neutrosophic scores using the mapping function displayed in Table 2. Each language expression is transformed to the corresponding neutrosophic value. The priority assigned to the linguistic phrase by the cloud user is then transformed into a neutrosophic value and showed in Table 5 and Table 6.

Table 5. Neutrosophic CR

Cloud service provider	Availability	Throughput	Successability	Reliability
AmazonHistoricalPricing	<0.96,0.01,0.96>	<0.01,0.96,0.96>	<0.88,0.60,0.90>	<0.60,0.90,0.90>
GoogleSearchService	<0.58,0.70,0.77>	<0.01,0.96,0.96>	<0.60,0.90,0.90>	<0.68,0.80,0.85>
ClientService	<0.88,0.60,0.90>	<0.96,0.01,0.96>	<0.88,0.60,0.90>	<0.78,0.65,0.54>
Conversor	<0.60,0.90,0.90>	<0.01,0.96,0.96>	<0.50,0.50,0.50>	<0.73,0.60,0.80>
AreaService	<0.50,0.50,0.50>	<0.58,0.70,0.77>	<0.68,0.80,0.85>	<0.60,0.90,0.90>

Cloud service provider	Latency	Response Time	RSCS	Cost
AmazonHistoricalPricing	<0.78,0.65,0.54>	<0.68,0.80,0.85>	<0.73,0.60,0.80>	<0.50,0.50,0.50>
GoogleSearchService	<0.58,0.70,0.77>	<0.50,0.50,0.50>	<0.78,0.65,0.54>	<0.73,0.60,0.80>
ClientService	<0.73,0.60,0.80>	<0.50,0.50,0.50>	<0.58,0.70,0.77>	<0.68,0.80,0.85>
Conversor	<0.78,0.65,0.54>	<0.88,0.60,0.90>	<0.96,0.01,0.96>	<0.01,0.96,0.96>
AreaService	<0.01,0.96,0.96>	<0.78,0.65,0.54>	<0.96,0.01,0.96>	<0.01,0.96,0.96>

Table 6. Neutrosophic Score

Criteria	Availability	Throughput	Successability	Reliability
Weight	<0.80,0.65,0.86>	<0.50,0.50,0.62>	<0.60,0.90,0.92>	<0.70,0.80,0.88>

Criteria	Latency	Response Time	RSCS	Cost
Weight	<0.90,0.60,0.92>	<0.80,0.65,0.86>	<0.70,0.80,0.88>	<0.50,0.50,0.62>

4.1.7 Computation of scored CR

The scored CR is produced by multiplying the neutrosophic criteria weights by the neutrosophic CR using Equation (4). Equation (5) shows how to create a scored neutrosophic CR element and compute its truth, indeterminacy, and falsity values in a neutrosophic environment. The scored CR is shown in Table 7.

Table 7. Scored neutrosophic CR

Cloud service provider	Availability	Throughput	Successability	Reliability
MAPPMatching	<0.921,0.01,0.921>	<0.01,0.9216,0.9216>	<0.7744,0.36,0.81>	<0.36,0.81,0.81>
Compound2	<0.556,0.07,0.739>	<0.01,0.9216,0.9216>	<0.528,0.54,0.81>	<0.40,0.72,0.765>
USDAData	<0.844,0.06,0.864>	<0.0096,0.0096,0.9216>	<0.7744,0.36,0.81>	<0.46,0.58,0.48>
GBNIRHolidayDates	<0.57,0.009,0.864>	<0.01,0.9216,0.9216>	<0.44,0.3,0.45>	<0.43,0.54,0.72>
CasUsers	<0.48,0.005,0.48>	<0.058,0.672,0.7392>	<0.598,0.48,0.765>	<0.36,0.81,0.81>

Cloud service provider	Latency	Response Time	RSCS	Cost
MAPPMatching	<0.608,0.422,0.291>	<0.4624,0.64,0.7225>	<0.5329,0.36,0.64>	<0.25,0.25,0.25>
Compound2	<0.452,0.455,0.415>	<0.34,0.4,0.425>	<0.5694,0.39,0.432>	<0.365,0.3,0.4>
USDAData	<0.5694,0.39,0.432>	<0.34,0.4,0.425>	<0.4234,0.42,0.616>	<0.34,0.4,0.425>
GBNIRHolidayDates	<0.608,0.422,0.291>	<0.5984,0.48,0.765>	<0.7008,0.006,0.768>	<0.005,0.48,0.48>
CasUsers	<0.007,0.624,0.518>	<0.5304,0.52,0.459>	<0.7008,0.006,0.768>	<0.005,0.48,0.48>

4.1.8 Determination of PNS and NNS

Cost-benefit analysis is used to determine the (PNS) and (NNS). The best and worst options are PNS and NNS, respectively. Equations (6) and (7) are used to calculate the PNS and NNS, respectively. Table 8 displays the computed values for PNS and NNS.

Table 8. PNS and NNS values

	Availability	Throughput	Successability	Reliability
PNS	<1,0,0>	<1,0,0>	<1,0,0>	<1,0,0>
NNS	<0,1,1>	<0,1,1>	<0,1,1>	<0,1,1>

	Latency	Response Time	RSCS	Cost
PNS	<0,1,1>	<0,1,1>	<0,1,1>	<0,1,1>
NNS	<1,0,0>	<1,0,0>	<1,0,0>	<1,0,0>

4.1.9 Calculation of the grade of each alternative from PNS and NNS

The grade of each alternative from PNS and NNS is computed using Equation (8) and Equation (9) respectively, when $\boldsymbol{S}^{+} = 1$ or $\boldsymbol{S}^{-} = 1$ and results are shown in Table 9.

4.1.10 Determination of Stability of each Cloud service provider and Ranking

Each cloud service provider's stability is calculated using Equation (10) and its value is displayed in Table 8. Finally, the cloud service providers are evaluated according to the importance of grades. The cloud service provider with the highest-grade score is rated first, and the one with the lowest score is ranked last. According to the case study, " GoogleSearchService " is ranked highest among cloud service providers, whereas "

ClientService " is ranked lowest. In accordance with the importance of the criteria parameters provided by the cloud user, the cloud service provider's rankings are GoogleSearchService, AmazonHistoricalPricing, Conversor, AreaService, and ClientService the ranking process is shown in Table 9.

Table 9. ranking table

Cloud service provider	S+	S-	Stability (%)	Rank
AmazonHistoricalPricing	5.63	7.41	56.80875373	2
GoogleSearchService	4.71	7.15	60.28713781	1
ClientService	5.60	5.72	50.48675772	5
Conversor	5.15	6.64	56.3278466	3
AreaService	5.30	6.01	53.12079824	4

4.2 Comparison and Computational Time

Several currently available multi-criteria decision-making strategies are used to compare the performance of the proposed framework (AHP, TOPSIS, and VIKOR Neutrosophic). On a machine with an Intel i5-1035G4 10th Gen processor clocked at 1.1 GHz, 16 GB of RAM, and Windows 10 64-bit installed with simulation software OnScale Solve, the experiment was carried out, and it was successful in delivering great performance in a little period of time, especially with the various suppliers. Utilizing 1507 cloud service providers and the eight criteria, the study was conducted. Because it completes Equation 1, Algorithm 1's implementation shortens the computation time. Equation (8) and Equation (9), which results in diminishing algorithmic steps, if and only if S+=1 or S-=1. First, we measured the calculation time while testing the framework with 100 cloud service providers. After that, we steadily raised the number of cloud service providers while keeping track of how long each iteration of the computation took. In Table 10, the suggested framework's computation time is contrasted with that of several multi-criteria decision-making techniques as AHP, TOPSIS, and VIKOR Neutrosophic. And Figure 1 compares them side by side.

Table 10. Computational time

No. Of Cloud service providers	Proposed method (sec)	Vikor Neutrosphic(sec)	TOPSIS (sec)	AHP (sec)
100	0.005	0.005	0.005	0.005
200	0.01	0.01	0.01	0.01
300	0.015	0.015	0.019	0.023
400	0.02	0.021	0.025	0.029
500	0.025	0.0251	0.0291	0.0331
600	0.03	0.032	0.036	0.04
700	0.035	0.039	0.043	0.047
800	0.04	0.046	0.05	0.054
900	0.045	0.0515	0.0555	0.0595
1000	0.05	0.057	0.061	0.065

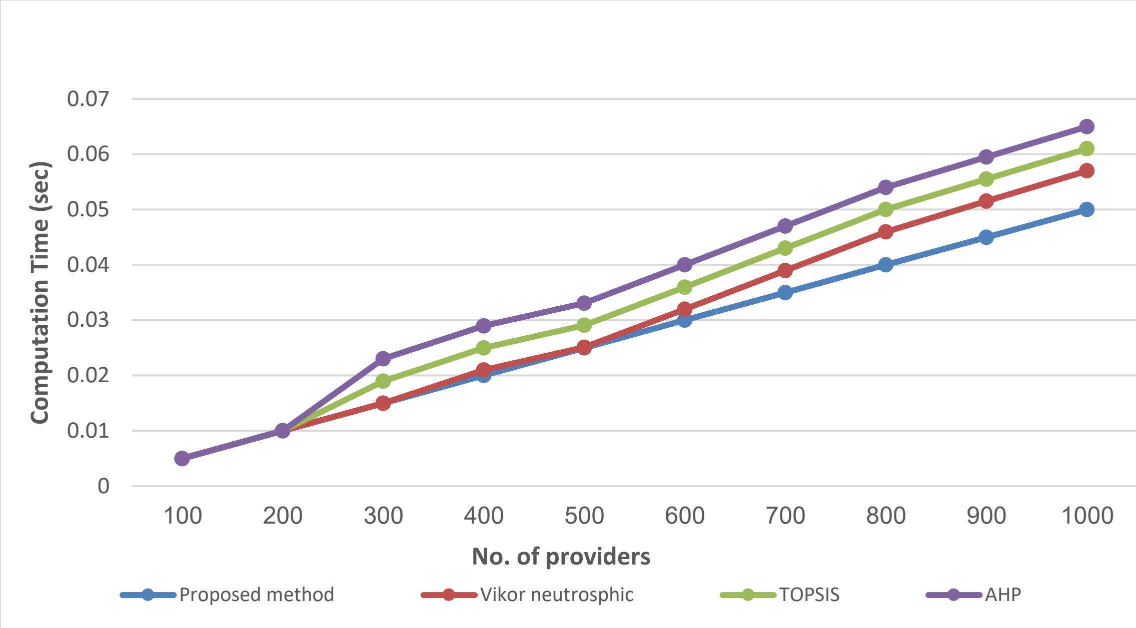

Fig.1 Comparison chart between the proposed method and other methods

5. Conclusion

When a firm plans to move its work to cloud architectures for a number of properties, choosing cloud service providers is one of the biggest challenges. This article offers a framework for choosing the best cloud service provider for every stakeholder. The framework can handle and complete the missing values during data collection using a modified version of GAN, and after the data has been completed, it can rank the cloud service providers in accordance with the requirements of the company using the neutrosophic multi-criteria decision-making method. This study has demonstrated the framework's effectiveness and accuracy in picking suitable cloud service providers and imputations of the missing data. Particularly when using a large number of cloud service providers, the proposed solution has taken less time than the others.

In future work, the proposed framework can be improved to include group decision making when choosing a cloud service and by combining it with other MCDM techniques. To handle vagueness more effectively, it can also be extended to an interval-valued neutrosophic set or combined with rough set theory.

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