# Single Valued Neutrosophic Sets MCDM Method for Ranking Technologies of Cloud Computing

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**Abstract**

By automating several formerly labor-intensive processes, like setting up a company's communications network, cloud computing technology (CCT) offers significant benefits to organizations and individuals. CCT is a game-changer for every sector since it enables businesses of all stripes to forego asset ownership in favor of paying variable subscription fees. The assessment of the CCT provider selection (PS) issue necessitates the identification of a set of appropriate selection requirements and their sub-criteria. Another goal is to utilize this suggested method in a real-world case study after presenting a robust integrated system for assessing and choosing the best CCT supplier. There are a variety of qualitative and quantitative characteristics that might be at odds with one another or even unclear in CCT PS, making it a challenging multi-criteria selection issue. The single valued neutrosophic set is used to overcome the vague data. The neutrosophic TOPSIS method is used to give weights of criteria and rank the alternatives. The application is introduced by the results of the neutrosophic TOPSIS method.

**Keywords**: Single Valued Neutrosophic Sets; Cloud Computing; MCDM; Ranking

## 1. Introduction

As a project develops, a steady stream of disparate data is produced, making building an information-intensive sector. Information gathered at various points in a project is often kept in separate locations (e.g., a team computer, an individual's computer, a mobile device, etc.). Since making incorrect choices due to a lack of context may significantly slow down a project and harm its success and financial viability, combining information is essential for total project management[1], [2].

To keep, manage, and evaluate data from its suppliers, the standard ICT approach is to purchase a high-end capability computer. The operating costs associated with deploying technologies on-premises (such as electricity, cooling, security, availability, and upgrades) are quite high. Therefore, it is not feasible to set up on-site information technology facilities for all projects owing to the high cost involved in doing so.

Additionally, it is often costlier to improve in-house computer infrastructure to match a sudden uptick in computing demands. Small and medium-sized businesses (SMEs) make up the vast majority of the building industry, and they simply cannot afford to build the kind of cutting-edge information and communications technology network that would allow them to take full advantage of today's digital advancements. So, the building trade is relatively untapped by technology[3], [4].



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Due to the high cost of failure, companies in the construction sector may be reluctant to embrace cutting-edge technologies. Despite the vast potential of cloud computing in the building sector, its use is still relatively uncommon. Cloud computing allows users to rent computer resources on demand and pay only for the time they use them. This is why the features of cloud computing are so well suited to the needs of SMEs[5], [6].

Since cloud computing does away with the need to purchase, set up, and maintain computer equipment, this removes a major barrier to the widespread use of ICT in the building sector. Scientists need to show building specialists the potential advantages of cloud computing to encourage the widespread use of innovation. The investigation's topic was inspired by the need to address this information gap[7], [8].

The process of making choices in real life entails picking the best option from a set of alternatives. Decision makers (DMs) must take into account several factors at once to choose the best possible option[9]–[14]. Since the 1970s, scientists have relied heavily on multiple criteria decision-making (MCDM) techniques. When considering a topic with many goals or standards, MCDM approaches have emerged as a central field of study[15], [16].

Even the most basic of fuzzy sets may not be suitable in more complex situations. The provided information may be unreliable or imprecise if it is incomplete[17], [18].

So the neutrosophic set is used to overcome the vague data. The single valued neutrosophic set has three membership functions named truth, indeterminacy, and falsity[19], [20].

**1.1 Summary Cloud Computing**

When it comes to managing and making use of computer hardware and software, cloud computing represents a major change. Organizations may now share both the physical and non-physical components of an IT infrastructure thanks to the development of Service Oriented Architecture (SOA), the foundation of cloud computing techniques. The goal is to spread out the expenses of computation by designing the architecture to be used more than once. Costs associated with setting up and maintaining a computer system are cut down considerably by these features. A member of an online shopping team could interpret "cloud computing" as "shareable data and communication Technology," although this is only one such interpretation. Figure 1 shows how much research has provided simplified depictions of cloud computing. The NIST description of cloud computing has become the most frequently used one[21], [22]. Figure 2 shows the model criteria, deployment, and service.

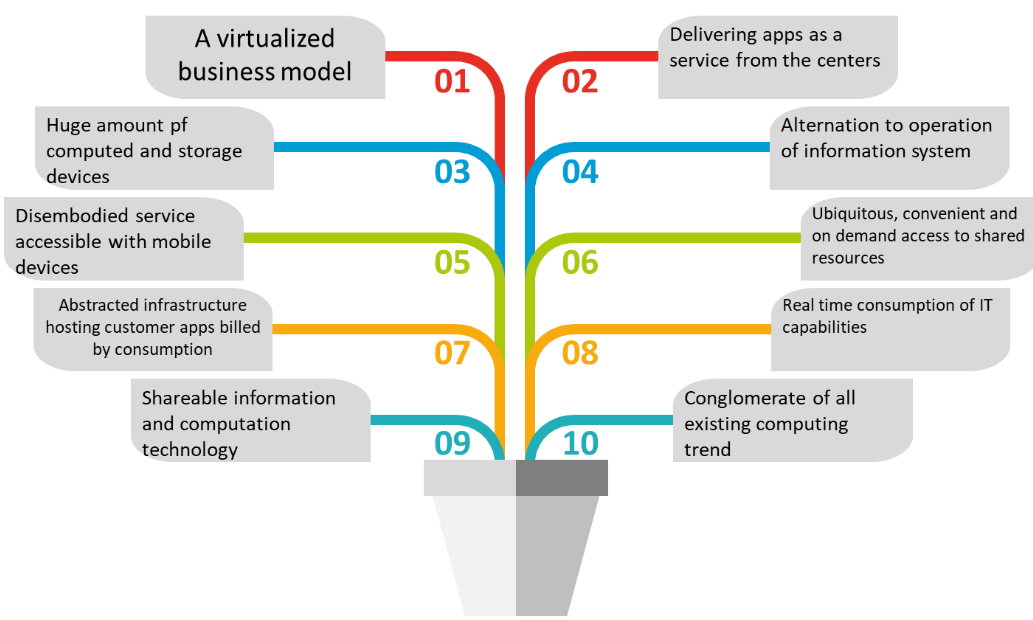


Figure 1. Definition of cloud computing



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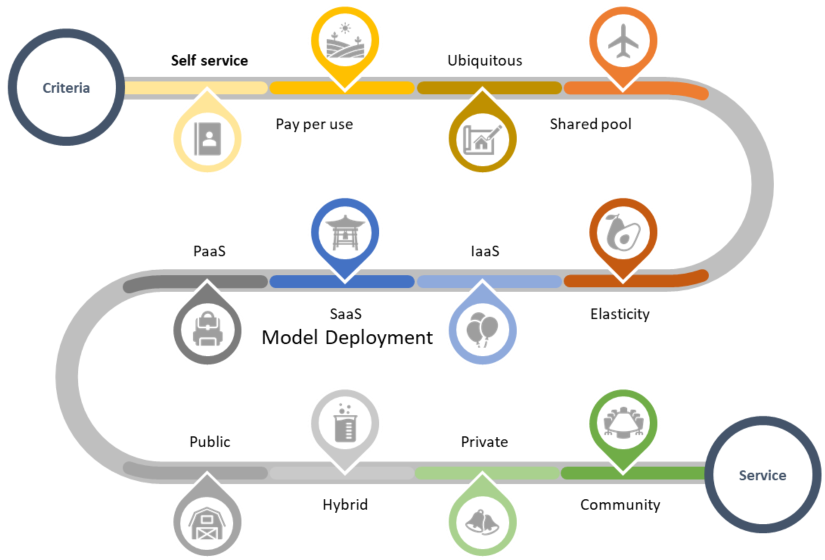


Figure 2. The model criteria, service and deployment of cloud computing

**2. Cloud Computing Models**

One of cloud computing's defining features is that its services may be accessed from anywhere at any time, making it a truly omnipresent technology. Due to the distributed nature of the computer's core structures, cloud services may be accessed from anywhere and on any device with an internet connection. (2) Having a shared pool indicates a multi-tenant architecture that can support a wide variety of users and software. This makes it possible for a large number of individuals to use a single computer resource while maintaining their distinct levels of privacy and security. (3) The elasticity property enables users to dynamically alter their requests for allocated computer resources. If a company suddenly sees a spike in traffic, its cloud system may expand to meet the increased demand. (4) The self-service on-request feature allows computing resources to be made available to customers in an automated fashion[23], [24].

In earlier times, customers had to place orders for computing resources, wait for them to arrive, and then do system installs before they could begin using the system. Until the network is completely operational, it will require a minimum of 24 hours. These days, consumers just input their payment information onto a cloud service supplier's website, and within minutes, they are privy to all the computing power they could ever need. In the cloud, (5) the pay-as-you-go characteristic enables customers to pay only for utilized services that are used, and (6) the online service portal allows customers to control their offerings independently of the cloud provider. Users are billed monthly based on their specific use of cloud resources, much as how utilities like as energy and water are billed[25], [26].

The deployment model for cloud-based applications might range from public to private to communal to hybrid. Installation strategies vary according to the kind of user who may get entry to the application and the means through which they gain entry. The public cloud is a multi-tenant environment in which data from many different individuals is handled simultaneously and made available to multiple users over the internet. Apps served in the public cloud may reside in a single data center or a network of data centers. The cloud supplier is alone in charge of and liable for all infrastructure upkeep. Most small organizations may benefit greatly from using the public cloud. Private clouds are housed on an organization's servers and are only accessible inside the company's internal network[27], [28].



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IT infrastructure as (IaaS), also known as the computing layer, offers simulated storage and computers for data processing and is one of the three kinds of services that make up the cloud. Users may rent scalable, web-based virtual storage space that can grow or shrink as needed[29], [30].

Cloud service firms spend billions of dollars building large data centers outfitted with backup power, social networking, and communication and housing hundreds of thousands of machines using virtualization technologies. To help their customers with issues with large amounts of dispersed data, service providers deploy data centers in multiple geographic locations throughout the globe[31], [32].

**3. Single-Valued Neutrosophic TOPSIS Method**

This section introduced the steps of the SVN-TOPSIS method as shown in Figure 3.

Step 1. Build the single-valued neutrosophic decision matrix

$$E = \begin{array}{c} CLodA_1 \\ \ldots.. \\ CLodA_m \end{array} \begin{bmatrix} (A_{11}, B_{11}, C_{11}) & \cdots & (A_{1n}, B_{1n}, C_{1n}) \\ \vdots & \ddots & \vdots \\ (A_{m1}, B_{m1}, C_{m1}) & \cdots & (A_{mn}, B_{mn}, C_{mn}) \end{bmatrix} \tag{1}$$

Where A, B, and C refer to the truth, indeterminacy, and falsity functions.

Step 2. Compute the weights of specialist

$$w_p = \frac{1-\sqrt{\frac{\left\{\begin{matrix}(1-A_P(x)^2)+ \\ (B_P(x)^2)+ \\ \left((C_P(x)^2)\right)\end{matrix}\right\}}{3}}}{\sum_{P=1}^{K}\left(1-\sqrt{\frac{\left\{\begin{matrix}(1-A_P(x)^2)+ \\ (B_P(x)^2)+ \\ \left((C_P(x)^2)\right)\end{matrix}\right\}}{3}}\right)} \tag{2}$$

Step 3. Compute the weighted average operator

$$AVergae = 1 - \prod_{k=1}^{r}\left(1 - A_{ij}^{r}\right)^{w_p}, \prod_{k=1}^{r}\left(B_{ij}^{r}\right)^{w_p}, \prod_{k=1}^{r}\left(C_{ij}^{r}\right)^{w_p} \tag{3}$$

Step 4. Compute the weights of the criteria

Step 5. Compute the neutrosophic ideal solution

$$I_j^{w^+} = \left(\begin{matrix} \left\{\begin{matrix}\left(\max\limits_i A_{ij}^{w^j} \mid j \in J_1\right), \\ \left(\min\limits_i A_{ij}^{w^j} \mid j \in J_2\right)\end{matrix}\right\}, \\ \left\{\begin{matrix}\left(\min\limits_i B_{ij}^{w^j} \mid j \in J_1\right), \\ \left(\max\limits_i B_{ij}^{w^j} \mid j \in J_2\right)\end{matrix}\right\}. \\ \left\{\begin{matrix}\left(\min\limits_i C_{ij}^{w^j} \mid j \in J_1\right), \\ \left(\max\limits_i C_{ij}^{w^j} \mid j \in J_2\right)\end{matrix}\right\} \end{matrix}\right) \tag{4}$$



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$$I_j^{w^-} = \begin{pmatrix} \left\{ \begin{matrix} \left( \min_i A_{ij}^{w^j} \mid j \in J_1 \right), \\ \left( \max_i A_{ij}^{w^j} \mid j \in J_2 \right) \end{matrix} \right\}, \\ \left\{ \begin{matrix} \left( \max_i B_{ij}^{w^j} \mid j \in J_1 \right), \\ \left( \min_i B_{ij}^{w^j} \mid j \in J_2 \right) \end{matrix} \right\}, \\ \left\{ \begin{matrix} \left( \max_i C_{ij}^{w^j} \mid j \in J_1 \right), \\ \left( \min_i C_{ij}^{w^j} \mid j \in J_2 \right) \end{matrix} \right\} \end{pmatrix} \tag{5}$$

Step 6. Compute the distance between positive and negative ideal solution

$$S^+ = \sqrt{\frac{1}{3n} \sum_{j=1}^{n} \left\{ \begin{matrix} \left( A_{ij}^{w_j}(x_j) A_{ij}^{w^+}(x_j) \right)^2, \\ \left( B_{ij}^{w_j}(x_j) - B_{ij}^{w^+}(x_j) \right)^2, \\ \left( C_{ij}^{w_j}(x_j) - C_{ij}^{w^+}(x_j) \right)^2 \end{matrix} \right\}} \tag{6}$$

$$S^- = \sqrt{\frac{1}{3n} \sum_{j=1}^{n} \left\{ \begin{matrix} \left( A_{ij}^{w_j}(x_j) A_{ij}^{w^+}(x_j) \right)^2, \\ \left( B_{ij}^{w_j}(x_j) - B_{ij}^{w^+}(x_j) \right)^2, \\ \left( C_{ij}^{w_j}(x_j) - C_{ij}^{w^+}(x_j) \right)^2 \end{matrix} \right\}} \tag{7}$$

Step 7. Compute the coefficient of closeness as:

$$F_i^* = \frac{S^-}{S^+ + S^-} \tag{8}$$

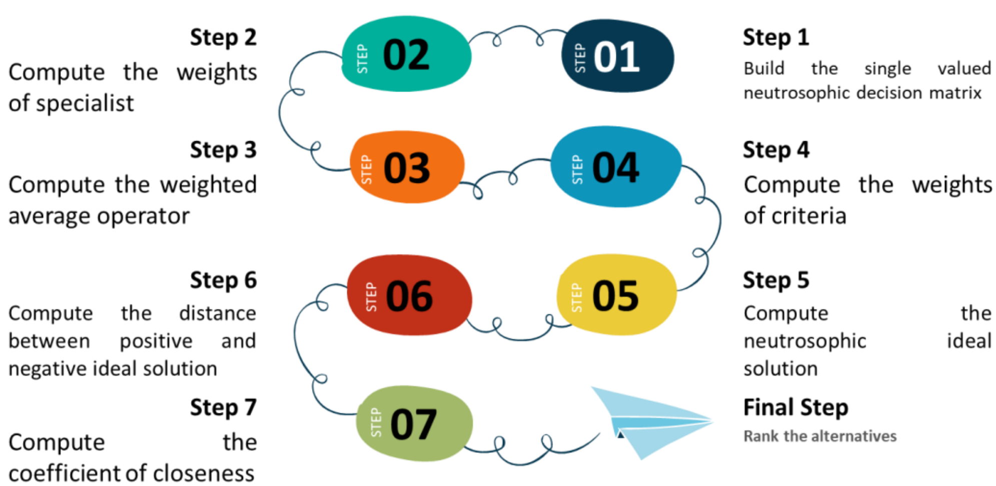


Figure 3. The steps of the SVN-TOPSIS method.



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## 4. Results

This section introduces the results of the SVN-TOPSIS method. This paper tends to select the best firm in cloud technology based on several factors. There are 17 criteria shown in Figure 4. There are seven firms of technology in the cloud are used in this paper. Let the experts evaluate the criteria and alternatives as shown in Table 1.

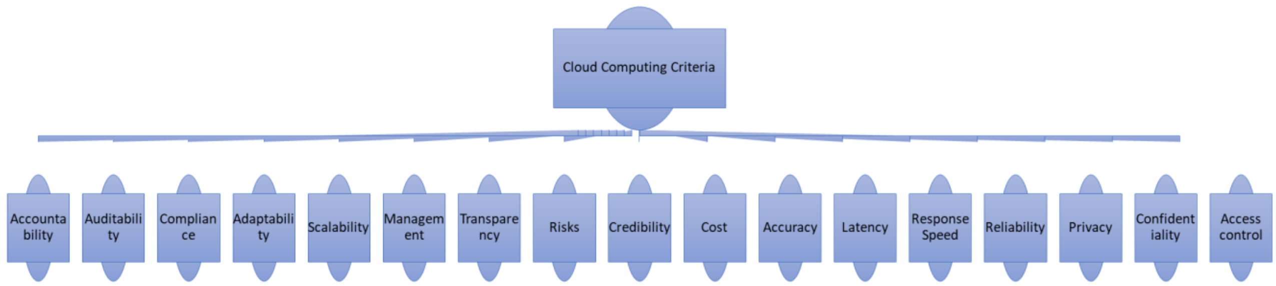


Figure 4. The Criteria of this paper.

Table 1. The decision matrix by the SVN-TOPSIS method.

| | $CTF_1$ | $CTF_2$ | $CTF_3$ | $CTF_4$ | $CTF_5$ | $CTF_6$ | $CTF_7$ | $CTF_8$ | $CTF_9$ | $CTF_{10}$ | $CTF_{11}$ | $CTF_{12}$ | $CTF_{13}$ | $CTF_{14}$ | $CTF_{15}$ | $CTF_{16}$ | $CTF_{17}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cloud $A_1$ | (1.0, 0.0, 0.0) | (0.7, 0.25, 0.3) | (0.9, 0.1, 0.1) | (0.9, 0.1, 0.1) | (0.1, 0.9, 0.9) | (0.7, 0.25, 0.3) | (1.0, 0.0, 0.0) | (0.4, 0.65, 0.6) | (0.4, 0.65, 0.6) | (1.0, 0.0, 0.0) | (0.7, 0.25, 0.3) | (0.8, 0.15, 0.2) | (0.7, 0.25, 0.3) | (0.2, 0.85, 0.8) | (0.7, 0.25, 0.3) | (0.8, 0.15, 0.2) | (1.0, 0.0, 0.0) |
| Cloud $A_2$ | (0.8, 0.15, 0.2) | (0.6, 0.35, 0.4) | (0.7, 0.25, 0.3) | (0.9, 0.1, 0.1) | (0.2, 0.85, 0.8) | (0.6, 0.35, 0.4) | (0.2, 0.85, 0.8) | (0.1, 0.9, 0.9) | (0.7, 0.25, 0.3) | (0.8, 0.15, 0.2) | (0.6, 0.35, 0.4) | (0.2, 0.85, 0.8) | (0.6, 0.35, 0.4) | (0.9, 0.1, 0.1) | (0.6, 0.35, 0.4) | (0.9, 0.1, 0.1) | (0.8, 0.15, 0.2) |
| Cloud $A_3$ | (1.0, 0.0, 0.0) | (0.5, 0.5, 0.5) | (0.6, 0.35, 0.4) | (0.1, 0.9, 0.9) | (0.2, 0.85, 0.8) | (0.5, 0.5, 0.5) | (1.0, 0.0, 0.0) | (0.2, 0.85, 0.8) | (0.6, 0.35, 0.4) | (0.8, 0.15, 0.2) | (0.5, 0.5, 0.5) | (0.2, 0.85, 0.8) | (0.5, 0.5, 0.5) | (0.1, 0.9, 0.9) | (0.5, 0.5, 0.5) | (0.7, 0.25, 0.3) | (1.0, 0.0, 0.0) |
| Cloud $A_4$ | (0.1, 0.9, 0.9) | (0.4, 0.65, 0.6) | (0.5, 0.5, 0.5) | (1.0, 0.0, 0.0) | (0.1, 0.9, 0.9) | (0.4, 0.65, 0.6) | (0.9, 0.1, 0.1) | (0.2, 0.85, 0.8) | (0.5, 0.5, 0.5) | (0.9, 0.1, 0.1) | (0.4, 0.65, 0.6) | (0.9, 0.1, 0.1) | (0.4, 0.65, 0.6) | (0.9, 0.1, 0.1) | (0.4, 0.65, 0.6) | (0.6, 0.35, 0.4) | (0.1, 0.9, 0.9) |
| Cloud $A_5$ | (0.9, 0.1, 0.1) | (0.1, 0.9, 0.9) | (0.4, 0.65, 0.6) | (0.2, 0.85, 0.8) | (0.7, 0.25, 0.3) | (0.7, 0.25, 0.3) | (1.0, 0.0, 0.0) | (0.4, 0.65, 0.6) | (0.7, 0.25, 0.3) | (0.9, 0.1, 0.1) | (0.2, 0.85, 0.8) | (0.7, 0.25, 0.3) | (0.4, 0.65, 0.6) | (0.7, 0.25, 0.3) | (0.2, 0.85, 0.8) | (0.5, 0.5, 0.5) | (1.0, 0.0, 0.0) |
| Cloud $A_6$ | (0.8, 0.15, 0.2) | (0.1, 0.9, 0.9) | (0.9, 0.1, 0.1) | (0.2, 0.85, 0.8) | (0.6, 0.35, 0.4) | (0.6, 0.35, 0.4) | (0.4, 0.65, 0.6) | (0.2, 0.85, 0.8) | (0.6, 0.35, 0.4) | (0.2, 0.85, 0.8) | (0.1, 0.9, 0.9) | (0.6, 0.35, 0.4) | (0.1, 0.9, 0.9) | (0.6, 0.35, 0.4) | (1.0, 0.0, 0.0) | (0.4, 0.65, 0.6) | (0.8, 0.15, 0.2) |
| Cloud $A_7$ | (1.0, 0.0, | (0.1, 0.9, | (0.4, 0.6 | (0.9, 0.1, | (0.5, 0.5, | (0.5, 0.5, | (0.9, 0.1, | (0.1, 0.9, | (0.5, 0.5, | (0.9, 0.1, 0.1) | (0.1, 0.9, 0.9) | (0.5, 0.5, 0.5) | (0.2, 0.85, | (0.5, 0.5, 0.5) | (0.2, 0.85, | (0.8, 0.15, | (1.0, 0.0, 0.0) |



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| | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0.0) | 0.9) | 5, 0.6) | 0.1) | 0.5) | 0.5) | 0.1) | 0.9) | 0.5) | | | | 0.8) | | 0.8) | 0.2) | |

Then compute the weights of experts. Then compute the weighted average operator by using Eq. (3). Then compute the weights of criteria as shown in Figure 5.

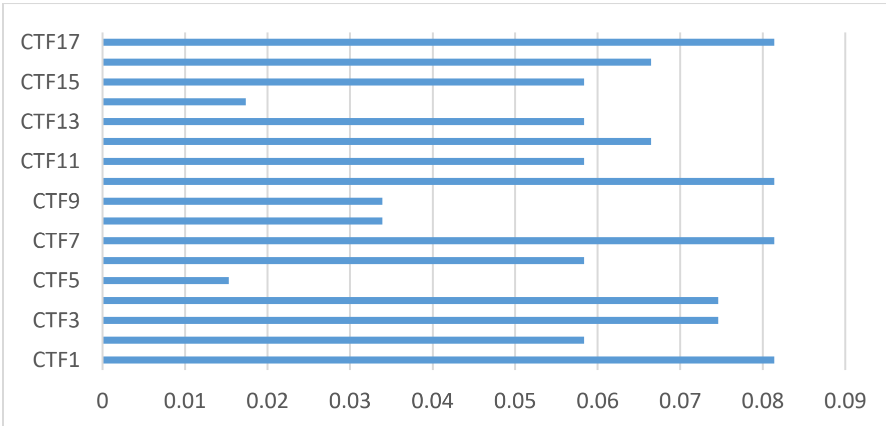


Figure 5. The importance of 17 factors

Then compute the neutrosophic ideal solution using Eqs. (4 and 5). Then compute the distance between positive and negative ideal solutions by using Eqs. (6 and 7). Then compute the closeness value by using Eq. (8) as shown in Figure 6. The first firm is the best and the fourth firm is the worst.

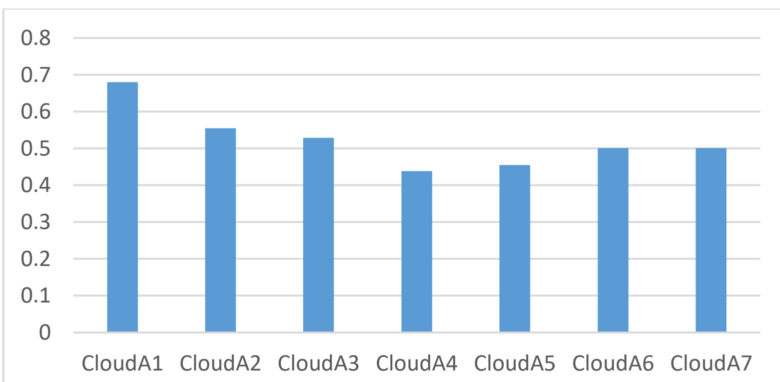


Figure 6. The rank of firms.

**5. Conclusion**

This paper introduced the framework with a single-valued neutrosophic set and the TOPSIS method to select the best technology for cloud computing. The neutrosophic set is used to overcome the vague data. The TOPSIS method is used to rank the technology of cloud computing. In this research, we describe an MCDM approach to addressing a common decision-making challenge in the field of cloud computing. There are 17 factors of cloud computing used in this paper and seven firms. The weights of the criteria are computed by the average method. Then the steps of the neutrosophic TOPSIS method are applied. The results show the first firm is the best and the fourth firm is the worst.

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