International Journal of Pure and Applied Mathematics
Volume 119 No. 15 2018, 2771-2782
ISSN: 1314-3395 (on-line version)
url: http://www.acadpubl.eu/hub/
Special Issue
http://www.acadpubl.eu/hub/

Comparing IaaS providers present in the market: using hybrid intuitionistic fuzzy technique combined with TOPSIS

Abhishek Srivastava[1], Yashi Mathur[2], Rana Majumdar[3], Ritu Gupta[4], Yugal Kumar[5]

Amity School of Engineering and Technology, Amity University Uttar Pradesh, India[1,2,3,4],
Department of Computer Science and Engineering, JUIT, Solan[5]

asrivastava8@amity.edu[1], yashimathur97@gmail.com[2], rmajumdar@amity.edu[3], ritu4006@gmail.com[4],
yugalkumar.14@gmail.com[5]

***Abstract*—In the past few years, cloud computing has advanced rapidly because of the increased demand of data centers and their services. The most basic category of Cloud computing is Infrastructure as a Service (IaaS) which is the process of providing the infrastructure such as networking hardware, storage media, etc. to the clients over the internet by the service provider on a pay-as-you-use basis. The major challenge faced by the clients is to choose among the many IaaS providers available in the market as to who can provide the best services keeping in mind certain criteria. This paper's main objective is to compare five IaaS providers present in the market on the basis of factors like cost, reliability, scalability and security to efficiently choose the most appropriate IaaS provider for their preferred services. The major factor of concern in this paper is cloud security while the other factors have a partial impact on the final decision. The methodology adopted is a hybrid intuitionistic fuzzy technique combined with TOPSIS method so as to rank the given alternatives.**

Keywords—Cloud computing; Infrastructure-as-a-Service (IaaS); Intuitionistic fuzzy set (IFS); TOPSIS; Multi-criteria decision making (MCDM); Cloud security

I. INTRODUCTION

In the present era, the advancement of technology is reaching new horizons and impacting the development of human race strongly. In this world of technology, users or organizations as a whole need computing services provided to them in order to develop, execute or implement their software applications. To resolve this purpose, the concept of cloud computing was evolved. Cloud Computing is a method by which on demand computing services such as servers, softwares, data centers, databases, et cetera can be delivered over the internet, i.e., the cloud. With the help of Cloud Computing, virtualization has reached a new level. [1] Lower cost, better security, faster recovery of data and better software testing are some of the benefits of virtualization due to Cloud Computing. Cloud computing services are made available to use by different companies which are known as cloud providers and can be categorized into three categories: "Infrastructure-as-a-service" (IaaS), "Platform as a service" (PaaS) and "Software as a service" (SaaS). The most fundamental category of Cloud Computing services is IaaS and it means renting IT infrastructure over the internet from a cloud provider. [2] Certain cloud providers supply IT infrastructure which may include networks, operating systems, servers, virtual machines (VMs) and storage on a pay-as-you-use basis. In IaaS, a virtual machine is enabled at the user's disposal with all the required computing services. The main problem faced by the users of IaaS clouds is selecting the appropriate cloud provider for a certain preferred service. A provider may provide IaaS service with minimal cost but it may come with security issues such as data breaches, malware injection, etc. which can be a major drawback for some businesses. Therefore, issues such as cloud security, cost, reliability etc. altogether need to be taken care of while selecting a particular IaaS provider. When a user deploys on a cloud platform, the infrastructure vendor gains the control and hence, it implements an adequate security policy for ensuring the reduced effect of risks. Therefore, cloud security is directly related to the various policies adopted by the IaaS providers for protecting the users from data breaches, hacked interfaces, account hijacking, etc. By reviewing the literature extensively, it was found that not much of attention is given on comparing the particular IaaS services of the cloud computing providers. [3] The prevailing research is suggestive of comparing the cloud solutions as a whole including all of its three services. This research paper uses the concept of a hybrid intuitionistic fuzzy decision-making method combined with the ranking technique TOPSIS for comparing the five shortlisted IaaS providers and ranking them by reviewing their aspects like security, cost, scalability and reliability.

The rest of the paper is divided in different sections as follows: Section 2 presents the five shortlisted IaaS providers and the criterion on the basis of which they are compared. Section 3 proposes the methodology used for comparing the shortlisted IaaS providers. The IFS-TOPSIS implication in the context of the purpose of this paper using arithmetical illustrations is given in Section 4. Lastly, Section 5 features the conclusions drawn from the elucidation of the results with the suggested future scope of this research.

II. INFRASTRUCTURE-AS-A-SERVICE

As cloud computing is emerging very rapidly, all of its three components are gaining popularity with IaaS being the major one. It is a provision which helps in providing virtualized resources via internet to the users. Various applications of IaaS include big data analytics, disaster recovery, providing data centers and virtual servers to organizations, support hybrid clouds, etc.[4] To select the most suitable IaaS vendor for the user's needs is a complex decision to make since a considerable number of players are presently available in the market. Cloud security is the key factor to keep in mind while selecting a particular IaaS provider. A provider can secure a user's data by adopting different sets of policies and technologies. Almost every alternative uses their own set of policies for securing the user's data. Since most of the organizations are adopting cloud computing and considering cloud security as the most significant barrier to more extensive and faster implementation of cloud computing, it is one of the main factors which should be taken in account while selecting any IaaS provider. Second is the cost which needs to be kept in mind while choosing among the many available options. No user wants a service which is good in performance but high in costs or low in costs but bad in performance. Third factor is the scalability which means the system's capability to work and adapt with the growing amount of workload. Lastly, the fourth factor is reliability which refers to the provider's ability to consistently perform and provide availability to its specifications. In this paper, five key players of IaaS are selected for comparison on the basis of the above discussed criteria. Although, there are many other alternatives available, the five alternatives, currently being the most used by the users are: Google Compute Engine (GCE), Amazon Elastic Compute Cloud (EC2), Microsoft Azure Virtual Machines (VM), IBM Softlayer and DigitalOcean.

Continuing this section, the basic characteristics of the five IaaS providers taken up in this paper are discussed below.

A. "Amazon Elastic Compute Cloud (EC2)"

"Amazon Elastic Compute Cloud" (Amazon EC2) is known to provide resizable, scalable and secure cloud computing capacity. It is a web service that lets you completely control your computing resources in the Amazon Web Services (AWS) environment. It charges the user for what is being used. It helps the developers to build up dynamic and flexible applications which are prone to failure by providing virtual servers, letting the user configure networking and security and administer storage.

B. "IBM Softlayer"

IBM Softlayer, originally found in 2005 and acquired by IBM in 2013, is IBM cloud's Infrastructure-as-a-Service component which is specialized in providing managed hosting and dedicated servers. For the users to hire, they provide the combination of "bare metal" servers and virtual servers along with a variety of database platforms, hypervisors and operating systems which are built on their extensive network infrastructure.

C. "Google Compute Engine"

Google Compute Engine (GCE) is the IaaS service offered by Google Cloud Platform (GCP). It lets the users build and run virtual machines for serving as big compute clusters in the Google cloud environment. Their virtual servers offer strong consistency of performance and are scalable and have unrelenting disk storage. [5] GCE allows the users to choose the zone and region where they want their data resources to be used and stored.

D. "Microsoft Azure Virtual Machines"

Microsoft Azure Virtual Machines (VM) is the compute service (IaaS) offered by Azure to the administrators for launching on-demand, general purpose Linux and Microsoft Windows virtual machines in order to fulfill their computing solutions such as running applications, extending the data centers, software testing and development, etc. Azure VM offers the litheness of virtualization by providing users the control of deploying a software application in a very short span of time.

E. DigitalOcean

DigitalOcean is a cloud computing provider which focuses on making web infrastructure simple for software development. It provides the users Infrastructure-as-a-Service environment for helping them scale and organize software applications. For deploying the IaaS platform, DigitalOcean allows the developers to create and run Virtual Private Servers (VPS) which are known as "Droplets". It allows the users to select which region and data center the servers will run in.

III. PROPOSED METHODOLOGY

In the past, various approaches are put forward for aiding the decision makers in multi-criteria decision analysis in pursuance of choosing the best for their own decisions. These approaches are broadly classified into two categories:

1. The unique approach of synthesis techniques such as Weighted sum, SMART, MAVT,AHP, UTA, TOPSIS;
2. The outranking techniques of synthesis such as PROMETHEE, MACBETH and ELECTRE (Zardari et al. 2015; Boutkhoum et al. 2015).

In this paper, the hybrid intuitionistic fuzzy decision making methodology combined with the ranking technique TOPSIS has been selected for the process of ranking the given alternatives and choosing the most appropriate one for the users. [6] This method has been chosen because it's capable of dealing with multi criteria decision making issues in undetermined environments and because of its logical ability to represent the rationale of peoples' opinion using a basic computation procedure.

A. "Intuitionistic Fuzzy Set"

IFS was originated in 1986 by Atanassov. [7] It is the extension of the classical "Fuzzy Set Theory", which is an appropriate way for dealing with imprecision. In the past, IFS has been applied in many areas for instance, pattern recognition (Wang and Xin 2005; Zhang and Fu 2006; medical diagnosis reasoning (Szmidt and Kacprzyk 2001, 2004, Vlachos and Sergiadis 2007); Hashem et al. 2015; De et al. 2001) and decisionmaking issues (Xu and Yager 2006, 2008; Xu 2007; Wang 2009; Vishwakarma et al. 2016; Liu and Wang 2007; Chen and Tan 1994; Atanassov et al. 2005). [8][9]

IFS R in a finite set Y can be described as follows:

$R = \{(y, \lambda_R(y), \gamma_R(y)) | y \in Y\}$, where $\lambda_R(y)$ is a membership function and $\gamma_R(y): Y \to [0,1]$ is a nonmembership function, such that

$$0 \le \lambda_R(y) + \gamma_R(y) \le 1$$

There is another parameter of intuitionistic fuzzy set which is called the "Intuitionistic Fuzzy Index" or the degree of hesitation as to whether x belongs to A or not. It is denoted by $\mu_R(y)$. [8]

$$\mu_R(y) = \mathbf{1} - \lambda_R(y) - \gamma_R(y) \qquad (1)$$

It's obvious that for every $y \in Y, 0 \leq \mu_R(y) \leq 1$.

If the $\mu_R(y)$is higher in value, it is said that facts about y have more uncertainty and if the $\mu_R(y)$ is lower in value, facts about y have more certainty.

Let there be two intuitionistic fuzzy sets, R and P belonging to set Y, then the cross product between R and P can be defined as:

$$R \otimes P = \{\lambda_R(y).\lambda_P(y), \gamma_R(y) + \gamma_P(y) - \gamma_R(y).\gamma_P(y) | y \in Y\} \qquad (2)$$

B. "Intuitionistic fuzzy TOPSIS"

Let there be a set of criteria given by $Y = \{Y_1, Y_2, \dots, Y_n\}$ and $R = \{R_{1,}R_{2,} \dots, R_m\}$ be a set of alternatives.

The process for Intuitionsitic Fuzzy TOPSIS method is described in a step-by-step manner and elaborated below:

Step 1: In this stage, the decision makers' weights are determined.

Let 'l' be the number of decision makers whose importance will be expressed in intuitionistic fuzzy numbers and will be considered as linguistic terms.

Let $E_i = (\lambda_i, \gamma_i, \mu_i)$ be an intuitionistic fuzzy number for rating the i^{th}decision maker. Then to obtain the weight of the i^{th} decision maker, the following formula is used:

$$\psi_i = \frac{\left(\lambda_i + \mu_i\left(\frac{\lambda_i}{\lambda_i + \gamma_i}\right)\right)}{\sum_{i=1}^{l}\left(\lambda_i + \mu_i\left(\frac{\lambda_i}{\lambda_i + \gamma_i}\right)\right)} \qquad \text{where, } \sum_{i=1}^{l} \psi_i = 1 \qquad (3)$$

Step 2: In this stage, an "Aggregated Intuitionistic Fuzzy Decision Matrix" is constructed on the basis of the judgments of decision makers.

Let $F^{(i)} = (f_{jk}^{(i)})_{uxv}$ be an IF decision matrix for every decision maker. Each decision maker's weight is denoted by the set $\psi = \{\psi_1, \psi_2, \psi_3, \dots \psi_l\}$ and $\sum_{i=1}^{l} \psi_i = 1, \psi_i \in [0, 1]$. In this method of group decision-making, every individual decision opinion will be combined into a single group judgment for constructing an "Aggregated Intuitionistic Fuzzy Decision Matrix". For facilitating it, the use of IFWA operator is done which was proposed by Xu (2007). [10]

$F = (f_{uv})_{max}$, where

$$w_k = IFWA_\psi(f_{jk}^{(1)}.f_{jk}^{(2)} \dots f_{jk}^{(l)}$$

$$= \psi_1 f_{jk}^{(1)} \oplus \psi_2 f_{jk}^{(2)} \oplus \dots \oplus \psi_l f_{jk}^{(l)}$$

$$= \left[1 - \prod_{i=1}^{l}(1 - \lambda_{jk}^{(i)})^{\psi_i}, \prod_{i=1}^{l}(\gamma_{jk}^{(i)})^{\psi_i}, \prod_{i=1}^{l}(1 - \lambda_{jk}^{(i)})^{\psi_i} - \prod_{i=1}^{l}(\gamma_{jk}^{(i)})^{\psi_i}\right] \qquad (4)$$

Here,

$$f_{jk} = \left(\lambda_{R_k}(y_k), \gamma_{R_k}(y_k), \mu_{R_k}(y_k)\right) \quad (j = 1, 2 \dots u; \; k = 1, 2, 3 \dots v)$$

The definition of this matrix given below:

$$F = \begin{bmatrix} f_{11} & f_{12} & \cdots & f_{1v} \\ f_{21} & f_{22} & \cdots & f_{2v} \\ \vdots & \vdots & \ddots & \vdots \\ f_{u1} & f_{u2} & \cdots & f_{uv} \end{bmatrix} \tag{5}$$

Step 3: The weights of all the criteria are determined.

Importance of each criterion is different and all of them are not supposed to have equal importance. To deal with this, a set of ranks of importance is assumed as X. For obtaining X, all the discrete opinions for the importance of every criterion of the decision makers are combined.

Let there be any intuitionistic fuzzy number denoted by $x_k^{(i)} = \left[\lambda_k^{(i)}, \gamma_k^{(i)}, \mu_k^{(i)}\right]$ which is allocated by the i^{th} decision maker. Subsequently, the IFWA operator is used for calculating the importance degrees of the criteria. [10]

$$w_k = IFWA_{\psi}(x_k^{(1)}.x_k^{(2)} \dots x_k^{(l)})$$

$$= \psi_1 x_k^{(1)} \oplus \psi_2 x_k^{(2)} \oplus \dots \oplus \psi_l x_k^{(l)}$$

$$= \left[1 - \prod_{i=1}^{l}(1 - \lambda_{jk}^{(i)})^{\psi_i}, \prod_{i=1}^{l}(\gamma_{jk}^{(i)})^{\psi_i}, \prod_{i=1}^{l}(1 - \lambda_{jk}^{(i)})^{\psi_i} - \prod_{i=1}^{l}(\gamma_{jk}^{(i)})^{\psi_i}\right] \tag{6}$$

$$X = [x_1, x_2, x_3, \dots x_k]$$

Here, $x_k = (\lambda_k, \gamma_k, \mu_k)$ $(k = 1, 2, 3, \dots v)$.

Step 4: In this stage, “Aggregated Weighted Intuitionistic Fuzzy Decision Matrix” is constructed.

Following step 3 and 4, the “Aggregated Weighted IF Decision Matrix” is calculated by the following formula.

$$F \otimes X = \left\{\left(y, \lambda_{R_j}(y) \cdot \lambda_X(y), \gamma_{R_j}(y) + \gamma_X(y) - \gamma_{R_j}(y) \cdot \gamma_X(y)\right)\right\} | y \in Y$$

and

$$\mu_{R_i \cdot X}(y) = 1 - \gamma_{R_j}(y) - \gamma_X(y) - \lambda_{R_j}(y) \cdot \lambda_X(y) + \gamma_{R_j}(y) \cdot \gamma_X(y) \tag{7}$$

So, the “Aggregated Weighted IF Decision Matrix” is given as:

$$F = \begin{bmatrix} f'_{11} & f'_{12} & \cdots & f'_{1k} \\ f'_{21} & f'_{22} & \cdots & f'_{2k} \\ \vdots & \vdots & \ddots & \vdots \\ f'_{j1} & f'_{j2} & \cdots & f'_{jk} \end{bmatrix}$$

An element of the above matrix can be defined as:

$$S^{+}=\sqrt{\frac{1}{2n}\sum_{j=1}^{n}\left[\left(\lambda_{A_iW}(x_j)-\lambda_{A+W}(x_j)\right)^2+\left(\gamma_{A_iW}(x_j)-\gamma_{A+W}(x_j)\right)^2+\left(\mu_{A_iW}(x_j)-\mu_{A+W}(x_j)\right)^2\right]}$$

$$S^{-}=\sqrt{\frac{1}{2n}\sum_{j=1}^{n}\left[\left(\lambda_{A_iW}(x_j)-\lambda_{A-W}(x_j)\right)^2+\left(\gamma_{A_iW}(x_j)-\gamma_{A-W}(x_j)\right)^2+\left(\mu_{A_iW}(x_j)-\mu_{A-W}(x_j)\right)^2\right]} \qquad (9)$$

$$F'_{jk}=\left(\lambda'_{jk},\gamma'_{jk},\mu'_{jk}\right)=\left(\lambda_{R_jX}(y_k),\gamma_{R_jX}(y_k),\mu_{R_jX}(y_k)\right)$$

Step 5: In this stage, the "Intuitionistic Fuzzy Positive-Ideal Solution" and "Intuitionistic Fuzzy Negative-Ideal Solution" are determined.

Let there be two criteria, benefit criteria and cost criteria and let J_1 and J_2 denote both of them respectively. R^+ is the "intuitionistic fuzzy positive-ideal solution" and R^- is the "intuitionistic fuzzy negative-ideal solution. We can obtain R^+ and R^-as:

$$R^{+}=\left(\lambda_{R+X}(y_k),\gamma_{R+X}(y_k)\right)$$

$$R^{-}=\left(\lambda_{R-X}(y_k),\gamma_{R-X}(y_k)\right)$$

Where

$$\lambda_{R+X}(y_k)=\left(\left(max_j\lambda_{R_jX}(y_k)\middle|k\in K_1\right),\left(min_j\lambda_{R_jX}(y_k)\middle|k\in K_2\right)\right)$$

$$\gamma_{R+X}(y_k)=\left(\left(min_j\gamma_{R_jX}(y_k)\middle|k\in K_1\right),\left(min_j\gamma_{R_jX}(y_k)\middle|k\in K_2\right)\right)$$

$$\lambda_{R-X}(y_k)=\left(\left(min_j\lambda_{R_jX}(y_k)\middle|k\in K_1\right),\left(max_j\lambda_{R_jX}(y_k)\middle|k\in K_2\right)\right)$$

$$\gamma_{R-X}(y_k)=\left(\left(max_j\gamma_{R_jX}(y_k)\middle|k\in K_1\right),\left(min_j\gamma_{R_jX}(y_k)\middle|k\in K_2\right)\right)$$

(8)

Step 6: The separation measures are determined.

The usage of normalized Euclidean distance is done for measuring the separation between alternatives on IFS in this paper. [11]Subsequent to the selection of distance measure, F^+ and F^-, the calculation of separation measures for every alternative from IF positive-ideal and negative-ideal solutions is done according to the Eq. (9).

Step 7: The "Relative Closeness Coefficient" to the intuitionistic idyllic solution is calculated.

Let there be any alternative R_j, the definition of the relative closeness coefficient is given as follows:

$$C_{j^+}=\frac{F_{j^-}}{F_{j^+}+F_{j^-}}$$

(10)

Step 8: The alternatives are ranked.

After the determination of the relative closeness coefficient for each alternative, the ranking of all the alternatives is done in descending order of C_{j^+}'s.

IV. EMPIRICAL ILLUSTRATION

The main purpose of this review paper is to find out the most adequate IaaS provider present in the market for the users keeping in mind the four selected criteria: cost, security, reliability and scalability. The most adequate IaaS provider from amongst the five existing alternatives: Amazon EC2, Google Compute Engine, Microsoft Azure VM, IBM Softlayer and Digital Ocean is decided based on the particular criteria using the posited methodology of hybrid intuitionistic fuzzy decision making combined with the technique of TOPSIS.

Step 1: In this stage, the decision makers' weights are determined.

Based on the posited technique, firstly, the importance degree i.e., every decision maker's weights are calculated using (3) and Table 1 shows the linguistic terms. The calculated importance degrees of the decision makers are given in Table 2.

Linguistic Terms	**IFN's**	
	λ	γ
Very important	0.9	0.1
Important	0.75	0.2
Medium	0.5	0.45
Unimportant	0.35	0.6
Very unimportant	0.1	0.9

Table 1: Linguistic terms to rate the decision makers and importance of criteria

I	**II**	**III**
Very Important	**Important**	**Medium**
ψ_j		
0.406	0.356	0.238

Table 2: Importance degree assigned to decision makers

Linguistic Terms	**IFNs**	
	λ	γ
Extremely Good	1	0
Very Very Good	0.9	0.1
Very Good	0.8	0.1
Good	0.7	0.2
Medium Good	0.6	0.3
Fair	0.5	0.4
Medium Bad	0.4	0.5
Bad	0.25	0.6
Very Bad	0.1	0.75
Very Very Bad	0.1	0.9

Table 3: Linguistic terms for weights assigned to alternatives

Step 2: In this stage, an “Aggregated fuzzy decision matrix” is constructed based on the judgments of decision makers.

For constructing this matrix, the linguistic terms given in Table 3 are used and the decision makers are asked to assess and rate each alternative on the basis of the given criteria. The decision makers’ opinions are presented in Table 4.

On the basis of the aggregate of the judgments of the decision makers, the “Aggregated IF Decision Matrix” is constructed using (4) and is presented in Table 5.

Criteria	IaaS Provider	Decision Makers		
		I	***II***	***III***
Reliability (X1)	EC2	VVG	VG	VG
	Softlayer	G	G	MG
	GCE	VG	G	VVG
	Azure VM	G	VG	VG
	DigitalOcean	G	MG	MG
Security (X2)	EC2	VVG	VG	VG
	Softlayer	VG	G	VVG
	GCE	VG	VVG	VG
	Azure VM	G	MG	G
	DigitalOcean	MG	F	F
Cost (X3)	EC2	VG	G	G
	Softlayer	G	VG	MG
	GCE	VG	G	VG
	Azure VM	G	VG	G
	DigitalOcean	VG	G	VG
Scalability (X4)	EC2	VG	G	VG
	Softlayer	G	VG	MG
	GCE	MG	G	F
	Azure VM	VG	G	G
	DigitalOcean	MG	MG	MG

Table 4: Weights assigned by the decision makers to each alternative

	Reliability			Security			Cost			Scalability		
EC2	0.849	0.1	0.051	0.849	0.1	0.051	0.746	0.151	0.103	0.769	0.128	0.103
Softlayer	0.679	0.22	0.101	0.804	0.128	0.068	0.722	0.172	0.106	0.722	0.229	0.049
GCE	0.804	0.128	0.068	0.844	0.1	0.056	0.769	0.128	0.103	0.619	0.346	0.035
Azure VM	0.764	0.133	0.103	0.668	0.231	0.101	0.74	0.156	0.104	0.746	0.221	0.033
Digital Ocean	0.644	0.254	0.102	0.543	0.356	0.101	0.769	0.128	0.103	0.6	0.4	0

Table 5: Aggregated IF decision matrix

Step 3: The weights of all the criteria are determined.

The rating of the criteria independent of the given alternatives, i.e. how important a particular criterion is in context of IaaS services is done by the decision makers. They use the linguistic terms given in Table 1 for this purpose. The decision makers' opinions were then combined using (6) to determine the weights of each criterion which are shown in Table 6.

	λ	γ	μ
Reliability	0.861	0.128	0.011
Security	0.876	0.118	0.006
Cost	0.705	0.243	0.052
Scalability	0.68	0.267	0.053

Table 6: Weights assigned to the criteria

Step 4: In this stage, "Aggregated weighted intuitionistic fuzzy decision matrix" is created.

Followed by the determination of the weights of the criteria and decision makers, an Aggregated Weighted IF Decision Matrix is formed with the use of (7) which is shown in Table 7.

	Reliability			Security			Cost			Scalability		
EC2	0.731	0.215	0.054	0.744	0.206	0.05	0.526	0.357	0.117	0.523	0.361	0.116
Softlayer	0.585	0.32	0.095	0.704	0.231	0.065	0.509	0.373	0.118	0.491	0.435	0.074
GCE	0.692	0.24	0.068	0.739	0.206	0.055	0.542	0.34	0.118	0.421	0.521	0.058
Azure VM	0.658	0.244	0.098	0.585	0.322	0.093	0.522	0.361	0.117	0.507	0.429	0.064
Digital Ocean	0.554	0.349	0.097	0.476	0.432	0.092	0.542	0.34	0.118	0.408	0.56	0.032

Table 7: Aggregated Weighted IF Decision Matrix

Step 5: In this stage, the "Intuitionistic Fuzzy Positive-Ideal Solution" and "Intuitionistic Fuzzy Negative-Ideal Solution" are determined.

Since some of the criteria are cost criteria and some are benefit criteria, the calculation of IF positive and negative ideal solutions is done using (8) and results are shown in Table 8.

	Reliability			Security			Cost			Scalability		
R+	0.731	0.215	0.054	0.744	0.206	0.05	0.542	0.34	0.118	0.523	0.361	0.116
R-	0.554	0.349	0.097	0.476	0.432	0.092	0.509	0.373	0.118	0.408	0.56	0.032

Table 8: IF positive ideal and negative ideal solutions

Step 6 & 7: The "Separation measures" and "Relative Closeness Coefficient" to the intuitionistic idyllic solution are calculated.

On the basis of the normalized Euclidian distance, the separation measures and their relative closeness coefficients are calculated using (9) and (10). The results are shown in Table 9.

	F+	F-	Cj+
EC2	0.008	0.172	0.956
Softlayer	0.077	0.122	0.613
GCE	0.072	0.141	0.662
Azure VM	0.084	0.096	0.533
DigitalOcean	0.172	0.0165	0.088

Table 9: Separation measures and closeness coefficients

Step 8: The alternatives are ranked.

On the basis of the "Relative Closeness Coefficient", the five alternatives are ranked in the decreasing fashion of their C_{i^+}'s: Amazon EC2 > Google Compute Engine > IBM Softlayer > Microsoft Azure VM > DigitalOcean.

V. CONCLUSION

The main aim of this review was to evaluate, rank and select the most effective Infrastructure-as-a-Service (IaaS) platform for the users putting forward a multi-criteria decision making analysis on the basis of Intuitionistic Fuzzy Set and TOPSIS technique. Because of the large storage and computation constraints associated with software development, software testing, functioning of dynamic applications, extension of data centers, etc, many companies tend to rely upon virtual servers and storage platforms provided by IaaS vendors for effective and reliable functioning and management. [12] In this situation, assessing and opting for the best suited IaaS provider serves as a multi-criteria decision problem encircling various differing criteria.

For this review, intuitionistic fuzzy sets (IFS) are used since they are the most appropriate approach for dealing with such sort of ambiguity as in the case of opting for the best suited IaaS provider as per the requirements of the users. [13][14] Rating every alternative with respect to every criterion is integrated in the IFS technique and the linguistic terms illustrated as intuitionistic fuzzy numbers were given as assignments for the importance factors (weights) for every criterion.

Moreover, the utilization of intuitionistic fuzzy averaging operator (IFWA) was done for aggregating the different decision makers' opinions. Additionally, the Euclidean distance was used to obtain the intuitionistic fuzzy positive-ideal and negative-ideal solutions. The calculation of relative closeness coefficients of alternatives and the ranking of alternatives was done.

The hybrid IFS-TOPSIS technique has a very high probability of succeeding in the field of multi criteria decision making (MCDM) issues because of its ability to constrain imprecise observation of decision makers. [15] Consequently, it would be a motivation to see that this hybrid IFS-TOPSIS technique is put in application to various disciplines of technology and management and the outcomes being assessed against the numerous existing MCDM techniques in the near future.

REFERENCES

[1] Zhang L, Wu C, Li Z, Guo C, Chen M, Lau FCM (2013) Moving big data to the cloud: an online cost-minimizing approach. Sel Areas Commun IEEE J 31:2710–2721

[2] C. Davatz, C. Inzinger, J. Scheuner and P. Leitner, "An Approach and Case Study of Cloud Instance Type Selection for Multi-tier Web Applications," 2017 17th IEEE/ACM International Symposium on Cluster, Cloud and Grid Computing (CCGRID), Madrid, 2017, pp. 534-543.

[3] N. Serrano, G. Gallardo and J. Hernantes, "Infrastructure as a Service and Cloud Technologies," in IEEE Software, vol. 32, no. 2, pp. 30-36, Mar.-Apr. 2015.

[4] Wang X, Cao J, Xiang Y (2015) Dynamic cloud service selection using an adaptive learning mechanism in multi-cloud computing. J Syst Softw 100:195–210

[5] Z. Li, L. OBrien, R. Ranjan and M. Zhang, "Early Observations on Performance of Google Compute Engine for Scientific Computing," 2013 IEEE 5th International Conference on Cloud Computing Technology and Science, Bristol, 2013, pp. 1-8.

[6] Sachdeva, N., Singh, O., Kapur, P.K. et al. Int J Syst Assur Eng Manag (2016) 7: 316. https://doi.org/10.1007/s13198-016-0455-x

[7] Atanassov KT (1999) Intuitionistic fuzzy sets. Springer, Heidelberg

[8] Atanassov K, Pasi G, Yager RR (2005) Intuitionistic fuzzy interpretations of multi-criteria multi-person and multi-measurement tool decision making. Int J Syst Sci 36(14):859–868

[9] Szmidt E, Kacprzyk J (2000) Distances between intuitionistic fuzzy sets. Fuzzy Sets Syst 114:505–518

[10] Xu ZS, Yager RR (2008) Dynamic intuitionistic fuzzy multi-attribute decision making. Int J Approx Reason 48:246–262

[11] Zhang CY, Fu HY (2006) Similarity measures on three kinds of fuzzy sets. Pattern Recogn Lett 27:1307–1317

[12] Snijders C, Matzat U, Reips UD (2012) Big data: big gaps of knowledge in the field of Internet science. Int J Internet Sci 7(1):1–5

[13] Chen SM, Tan JM (1994) Handling multi criteria fuzzy decision making problems based on vague set theory. Fuzzy Sets Syst 67:163–172

[14] Vlachos IK, Sergiadis GD (2007) Intuitionistic fuzzy information—applications to pattern recognition. Pattern Recogn Lett 28:197–206

[15] De SK, Biswas R, Roy AR (2001) An application of intuitionistic fuzzy sets in medical diagnosis. Fuzzy Sets Syst 117:209–213