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Comparison of models for the selection of cloud computing resources

Comparación de modelos para la selección de recursos de cloud computing

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ABSTRACT. Due to technological advances, organizations have to face many challenges to provide support through the use of Information Technology (IT) to carry out tasks that require computer skills. This may require the use of programs, data storage, development tools or IT capabilities, therefore it is important to adopt adequate resources for the tasks to be perform and thus meet required needs. It follows that the selection of resources and suppliers is a topic of interest and that it is closely related to the selection models, where those of mathematical-based development present results with greater consistency and offer the possibility of establishing an order. This article presents the characteristics of Cloud Computing (CC) and the technologies that allow its implementation; the hierarchical analytical process as a solution for multi-criteria decision making, where peer comparison and weighting lay the foundations of its development; and a class of aggregation operators that allows the individual assessment of criteria and alternatives. In addition, the comparison of results that arise from the application for the selection of service providers, will allow to evaluate each model and obtain the appropriate one for situations where there is a wide range of possibilities.

RESUMEN. Debido a los avances tecnológicos, las organizaciones tienen que enfrentar muchos desafíos para brindar apoyo mediante el uso de la Tecnología de la Información (TI) para llevar a cabo tareas que requieren habilidades informáticas. Esto puede requerir el uso de programas, almacenamiento de datos, herramientas de desarrollo o capacidades de TI, por lo tanto, es importante adoptar recursos adecuados para las tareas a realizar y así satisfacer las necesidades requeridas. De ello se deduce que la selección de recursos y proveedores es un tema de interés y que está estrechamente relacionado con los modelos de selección, donde los de desarrollo basado en matemáticas presentan resultados con mayor consistencia y ofrecen la posibilidad de establecer un orden. Este artículo presenta las características de Cloud Computing (CC) y las tecnologías que permiten su implementación; el proceso analítico jerárquico como solución para la toma de decisiones con criterios múltiples, donde la comparación y la ponderación entre pares sientan las bases de su desarrollo; y una clase de operadores de agregación que permite la evaluación individual de criterios y alternativas. Además, la comparación de resultados que surgen de la aplicación para la selección de proveedores de servicios, permitirá evaluar cada modelo y obtener el apropiado para situaciones en las que existe una amplia gama de posibilidades.

KEYWORDS: Cloud computing, Computational resources, Selection models, Service providers, Hierarchical analytical process, Aggregation operators.

PALABRAS CLAVE: Cloud computing, Recursos computacionales, Modelos de selección, Proveedores de servicios, Proceso analítico jerárquico, Operadores de agregación.

1. Introduction

Advances in the area of computer science and communications are transforming the way in which an organization accesses IT resources. The CC represents a new technological model through which organizations have access to a platform with technical characteristics such as scalability and elasticity; and functional as efficiency, to name a few. Accordingly, the CC can be defined as a model that allows omnipresent convenient network access on demand (Habbal, Abdullah, Mkpojiogu, Hassan & Benamar, 2017), to computer resources that allow scalability quickly and with little effort.

The ability to access computer resources is a feature that makes the use of CC in organizations attractive, because it allows reaching a set of applications and services through a data network or Internet. Similarly and more precisely, the National Institute of Standards and Technology (NIST), presents it as a technological model that allows ubiquitous, adapted and networked demand access to a shared set of configurable computing resources - networks, servers, storage equipment, applications and services-, which can be quickly provisioned released with reduced management effort or minimal interaction with the service provider (Mell & Grance, 2011).

It is possible to affirm that the delivery of services through a data network is what characterizes the CC and its use makes it convenient for an organization, because the applications necessary for the development of the activities are available, without the need for particular configurations and software installations in the user terminals, with the advantage that they can be accessed at any time and place. Accordingly, it provides the feeling of independence because they can use a variety of devices including personal computers, laptops (Notebooks), smart devices (Smartphones, Tablets), with no apparent need for the installation of dedicated software.

As for the IT support staff, the CC generates a change in the work model particularly referred to the installation of tools and applications in the user terminals, concentrating its task in other areas, such as the selection of computer resources, the correct operation of the data network and the ability to access the Internet.

From the above, it is possible to affirm that this paradigm has recently become a technological trend that has changed the way in which computing resources are offered and therefore has influenced the IT market motivated by elimination of the complex restrictions of the traditional computing environment such as space, time, energy and equipment costs.

These tools, applications and capabilities concentrated as computer resources must be properly selected and for this it is necessary to make use of some methodology that allows to relate the offer of the suppliers, with the opinions of the decision makers and obtain as a result the optimal resource, within a range of possibilities, for the development of some activity.

This article will be organized as follows: Section 2 will discuss the CC paradigm, the definitions considered relevant, their characteristics and models; Section 3 will present the computer resources offered by each model; Section 4 will present the hierarchical analytical process along with its characteristics and structure; in Section 5 the aggregation operators, their main models and the one considered appropriate for the selection of resources will be defined; in Section 6 the proposals will be validated by a real case; Section 7 will analyze the results obtained; ending with the Conclusions and future lines of work.

2. Cloud computing

Cloud computing is a paradigm that completely changes the way in which services and applications are accessed because it is done through a data network or the Internet. According to (Joyanes Aguilar, 2012) it states that the CC is the evolution of a set of technologies that affects the focus of organizations where a set of hardware and software, storage, services and interfaces facilitate the entry of information as a service.

Therefore the cloud is not a place, but an IT resource management method that replaces local machines and private data centers with virtual infrastructure. In this way, users access the virtual computing, network and storage resources that are available on-line through a remote provider. These resources can be provisioned instantaneously, which is particularly useful for organizations that need to scale their infrastructure or reduce it quickly in the face of fluctuating demand.

Here it is possible to recognize the keyword service, which should be divided into categories to determine: what services can be offered and how they are offered.

In addition, there are characteristics recognized as essential by NIST (Badger et al., 2014), which must be taken into account when deploying in the cloud.

2.1. Essential features

The NIST CC model provides five essential characteristics that differentiate it from traditional computing, thereby providing a basis for comparing cloud services and their implementation strategies.

Therefore, based on the definitions provided, the five characteristics that an implementation must have in order to be considered as CC are presented (Badger et al., 2014):

On-demand self-service, a consumer can unilaterally provision computing capabilities, as necessary, automatically without requiring any human interaction with each service provider. This means that any user of the cloud can have access to computing resources when he needs them and without any interaction with the staff in charge of the cloud, automatically and unilaterally, thereby achieving some independence for the resource management.

Broad network access, the capabilities are available through the network and are accessed through standard mechanisms that promote the use of heterogeneous platforms (for example, mobile phones, tablets, laptops and workstations). This guarantees that any user, with any operating system or device, has access to the services.

Rapid elasticity, capacities can be provisioned and released elastically, in some cases automatically, to scale rapidly in proportion to demand. Indicates that the resources must be granted according to the client's needs at the time the client requests them. The addition of resources can occur in two ways: horizontally (expanding the number of physical resources) or vertically (changing the current resources for others with higher capacities).

Resource pooling, the provider's computing resources are grouped to serve multiple consumers using a multi-user model, with different physical and virtual resources dynamically allocated and reallocated according to consumer demand. This allows different providers to share their resources among different users, reducing costs and maximizing their availability.

Measured service, cloud systems automatically control and optimize the use of resources by leveraging a measurement capability for the type of service offered (for example, storage, processing, bandwidth and active user accounts). The use of resources can be monitored, controlled and informed, providing transparency for both the provider and the consumer of the service used. This indicates that the use of any resource must be measured, audited and reported to the customer based on a measurement system previously agreed between the provider and the user. In this way the user is generated economic charges according to the capacity or characteristics of the contracted service.

2.2. Service model

They refer to the specific services that can be accessed on a CC platform (Joyanes Aguilar, 2012), also

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known as XaaS (something as a service), the NIST (Badger et al., 2014) presents and defines three standardized models which are: Software as a service (SaaS), Platforms as a service (PaaS) and Infrastructure as a service (IaaS).

SaaS: This service gives the consumer the ability to use the provider's applications running in a cloud infrastructure. They can be accessed through devices (with different technologies) through a client interface, such as a web browser (for example, web-based email or a user portal). The consumer does not have the ability to manage or control the lower or underlying cloud infrastructure such as the network, servers, operating systems, storage or even the capabilities of individual applications. Being exceptionally access to limited configurations regarding specific applications for the user.

PaaS: The consumer has the ability to implement created or new applications in the cloud infrastructure using programming languages and tools compatible with the provider. The consumer does not have the ability to administer or control the lower or underlying infrastructure of the cloud, which includes the network, servers, operating systems or storage, however they have control over the applications implemented and possibly the settings of the application hosting environment.

IaaS: The consumer has the ability to access processing, storage, networks and other computing resources where he can implement and execute arbitrary software, which may include operating systems and applications. In this case, the consumer does not manage or control the lower-level infrastructure, however it has control over the operating systems, storage, implemented applications and, possibly, limited control of the selected network components.

The possible services that can be offered and how they are organized according to their taxonomy are represented in Figure 1.

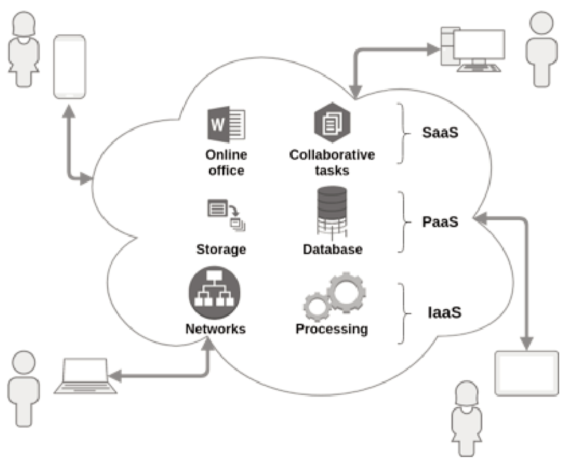

Figure 1. Representation of the service model. Source: Self-made.

2.3. Deployment model

According to NIST, the deployment model differentiates and defines the purpose of the cloud and also where it is located. Therefore this classification refers to the level and type of sharing of the resources contracted in the cloud with other similar entities or of different natures. Accordingly, there are four topologies to manage cloud computing resources, which are presented below.

Private cloud: In this type of model the cloud infrastructure is operated only for an organization, it can be managed by the organization or a third party and also exist on or off the premises.

Private cloud: In this type of model the cloud infrastructure is operated only for an organization, it can be managed by the organization or a third party and also exist on or off the premises.

Public cloud: The cloud infrastructure is available to the general public or to a large industrial group and is owned by an organization that sells cloud services.

Community cloud: The infrastructure in the cloud is shared by several organizations whose functions and services are common, thereby allowing collaboration between interest groups. It can be managed by organizations or a third party and can exist inside or outside the premises.

Hybrid cloud: Cloud infrastructure is a composition of two or more clouds (private, community or public) that remain as single entities but are linked by standardized technology that allows data and application portability.

The relationship between each of the categories is represented in Figure 2.

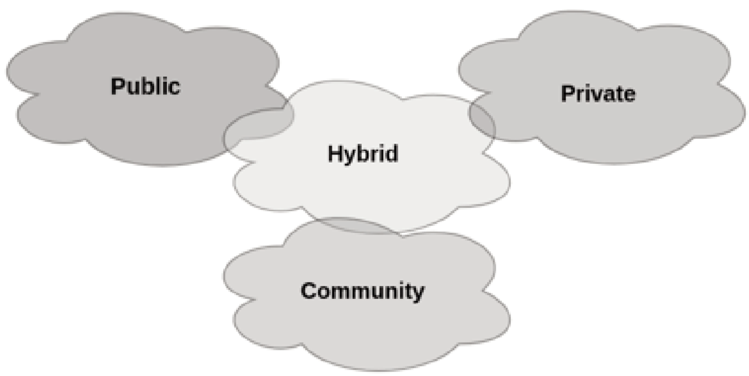

Figure 2. Representation of the deployment model. Source: Self-made.

3. Computer resources

The delivery of services, through the CC model, allows users and organizations to opt for those that are of interest for the development of their activities, therefore it is possible to classify resources with respect to each category of the service model.

So:

• resources such as office applications, content managers, applications for file sharing and collaborative work, among others, are those offered as SaaS.

• resources such as platforms for application development and implementation with which it is possible to model, create and execute applications in a controlled environment, are classified as PaaS.

• resources such as virtual machines (VMs), dedicated servers, physical and logical networks, storage blocks, among others, that can be used for data processing, instances of parallel execution of large volumes of information or storage, are those that are offered as IaaS.

This classification allows to affirm that the resources of IaaS lay the foundations for those of Paas and these for those of SaaS. Figure 3 shows the categories of services that each model can offer.

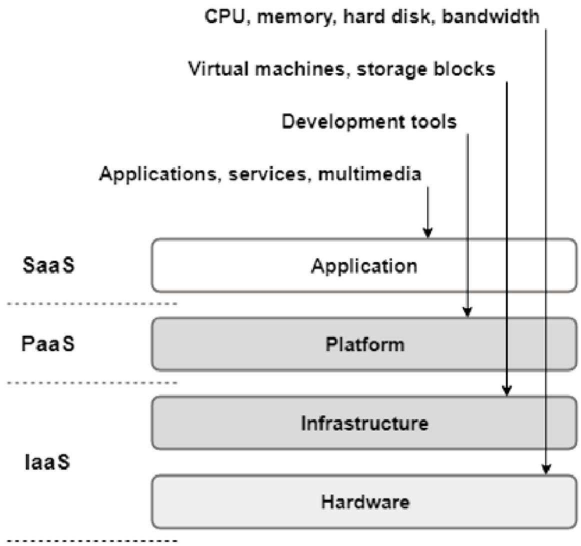

Figure 3. Representation of models and resources. Source: Prepared by the authors on the basis of (Kale & Mente, 2017).

Both the resources and the SaaS, PaaS and IaaS providers must be selected objectively and for this purpose it is necessary to have some model, where the characteristics offered can be contemplated, that the valuation is possible as a preference assignment and to present an order in the result of their alternatives. This leads to propose alternatives such as the Hierarchical Analytical Process (AHP) and the Aggregation Operators, which meet the requirements; In addition, its development and results can be compared in order to propose one of them as a general model for the selection of resources in the cloud.

4. Analytic hierarchy process

This model was defined by Saaty (Thomas L. Saaty: July 18, 1926 - August 14, 2017, distinguished university professor at the University of Pittsburgh, he is the creator, architect and principal theorist of the analytical hierarchy process) for a model that would help with the problem of complex decision making (Saaty, 1980). Articles on the subject suggest adopting resolution analysis techniques such as AHP, based on a quantitative method where an objective, criteria and alternatives are present. This method stands out among others due to its strong results based on the mathematical development present in its structure.

As expressed in (Berumen & Redondo, 2007), AHP is a logical and structured method that encourages complex decision making when there are many criteria and characteristics, by dividing the problem into a hierarchical structure, while (Medina, Cruz & Gomez, 2012) believes that AHP is a quantitative method criteria and features to support decision-making that contribute to the objectives of an organization. Similarly, (Guerrero-Liquet & Faxas-Guzmán, 2015) affirms that AHP is a proposal to order the analytical thinking that is distinguished by three principles: the principle of hierarchical construction, the principle of setting priorities and the principle of logical coherence.

According to the above, a complex characteristic can be divided into a group of simpler characteristics and determine how it influences the purpose of the decision. For this reason, this influence is represented by the values given to each characteristic or criterion. In other words, this facilitates the objectivity of the process and prevents the institution from making decisions.

Therefore, it is possible to affirm that AHP is a multi-criteria tool to associate the reality that an individual person perceives with a fair value scale that shows the relative priorities of the elements considered (Berumen & Redondo, 2007).

Therefore, a problem can be structured visually through a hierarchy of attributes that has at least three levels:

- The purpose or general objective of the problem at the top.
- The attributes or criteria that define alternatives in the medium.
- The alternatives in the lower level.

Once the hierarchical model is prepared, comparisons between pairs of elements must be made and numerical values assigned to the indicated preferences. Following the proposal of (Bermubez Irreño & Quiñonez Aguilar, 2018), it is possible to establish a work order using the AHP model as follows:

- Prioritization of the hierarchical model.
- Pairwise comparisons between elements.
- Evaluation of the elements by weight allocation (weighting).
- Measurement of alternatives subject to their weighted values.

The assignment of a weighted value to each criterion can be done using a table proposed by (Bermubez Irreño & Quiñonez Aguilar, 2018) based on Saaty's definitions, as seen in Table 1. It is important to note here, that although weighting is done using the defined table, it is the decision maker who assigns a value to each pair of alternatives and could imply a certain degree of subjectivity in the selection of preferences towards any particular alternative.

Numerical rating	**Verbal judgments of preferences**
9	Extremely preferred
8	Very strongly to extremely
7	Very strongly preferred
6	Strongly to very strongly
5	Strongly preferred
4	Moderately to strongly
3	Moderately preferred
2	Equally to moderately
1	Equally preferred

Table 1. Pair-wise comparison scale for AHP preferences. Source: Self-made.

5. Aggregation operators

So far the main aspects of CC and the technology that allows its development were presented, as well as a model based on the weighting and comparison that, as indicated above, implies a certain degree of subjectivity, this allows us to propose a model that allows the selection of those resources or suppliers. The consistency offered by the analysis of alternatives through a process of mathematical operations suggests to be adequate, therefore it is possible to propose aggregation operators as an alternative that meets the conditions presented.

There are authors who provide scientific information on the subject, among them (Peláez & Doña, 2003) expresses that the process of aggregation of information seems, in many applications, to be related to the development of intelligent systems. Aggregation can be seen in neural networks, fuzzy logic controllers, vision systems, expert systems and multi-criteria decision aids, according to (La Red Martínez, Doña, Peláez & Fernandez, 2011) in all decision-making processes, the use of aggregation operators is necessary, in addition (La Red Martínez & Acosta, 2014) states that a problem that the human being must face very often is that of having to add, merge or synthesize information, that is, combine a series of data from different sources, to reach a certain conclusion or take a certain decision, this involves the use of one or more aggregation operators.

In addition, it can be attached that the aggregation of information for decision-making encompasses all those situations in which several different opinions or criteria are available and it is intended to make a decision as consistent as possible with the starting information (Cubillo, Pradera & Trillas, 1998).

According to the proposal of (Dubois & Prade, 1988) it is possible to establish a taxonomy of the aggregation operators based on their behavior and are presented as:

- Conjunctive or intolerant behavior: it is desired that all the criteria to be combined are met and represented by any operator less than or equal to the minimum. The t-norm meet this requirement and therefore belong to this category.
- Disjunctive or tolerant behavior: it is enough that one of the criteria is satisfied to obtain a global satisfaction; it is represented by any operator greater than or equal to the maximum. In this case the t-conorms are suitable operators.
- Engagement behavior: on many occasions, it is desired to obtain an intermediate result that does not reflect either the absolute lack of compensation that the conjunctive behavior implies or the total compensation of the disjunctive behavior, said behavior is present in all those operators between the minimum and the maximum.

Based on the definitions and descriptions above, it is possible to propose a solution to the selection problem that allows obtaining results where the quantities that represent the services offered by the suppliers can be combined with the rating granted by the decision makers. Seen from another angle, it would correspond to merging the data offered by CC providers, about a particular service, and values that represent the weight that the decision maker has granted. This mechanism aligns with the conjunctive behavior, precisely with the Weighted Averages model, whose definition is given by (1).

$$M_w(x_1 \ldots x_n) = \sum_{i=1}^{n} w_i * x_i \quad (1)$$

Where, X_n values represent the quantities of the characteristics or criteria that will be evaluated, in addition to the W_n elements with values between 0 and 1, represents the weight that the decision maker applies to each element of X, which in addition to adding them their result must be 1, being represented according to (La Red Martínez, Doña, Peláez & Fernandez, 2011) by:

$$w_i \in [0,1] \text{y} \sum_{i=1}^{n} w_i = 1$$

In this way the result M_w corresponds to the combination of values that represents a service and those that correspond to the preference of the decision makers.

This particular case of the so-called average operators, is part of the family of Quasi-linear Averages where, in addition to the case presented, the group completes the Quasi-arithmetic and generalized Averages, which will be presented and argued why they were not taken in account.

From the contributions of (Calvo & Mesiar, 2003), it is possible to affirm that the case of Quasi-arithmetic Averages constitutes a particular case of Quasi-linear Averages in which the vector of weights is such that:

$$w_i = \frac{1}{n} \text{ for } i \in \{1 \ldots n\}$$

defined by:

$$M_f(x_1 \ldots x_n) = f^{-1}\left(\frac{1}{n}\sum_{i=1}^{n} f(x_i)\right) \quad (2)$$

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being f:I→Ra continuous and strictly monotonous function called average generating function.

Where it can be affirmed that the weight vector is defined $W_i=1/n$, this being the main reason for not having taken this model since using it leaves aside the will of the decision maker to weigh on a criterion, model or supplier.

On the other hand, the generalized means obtained when a function of the average is taken as a function of the type $f_{(x)}=x^{\alpha}$ with $\alpha \in R^*$ where a generalized mean is defined by:

$$M_{\alpha,w(x_1...x_n)} = (\sum_{i=1}^{n} w_i x_i^{\alpha})^{1/\alpha} \quad (3)$$

In this case, the vector W_i can be used to weigh with which it is aligned with what is required, however, incorporating the value α to adapt the equation, it can transform the values presented by the suppliers, which leads to a decrease in the representation of a raised reality.

Other alternatives to synthesize information is to use the variants that the Weighted Ordered Average (OWA) can offer, where both the vector of weights and the information values can be altered. In the case of weight vectors, they can be related to a function for example linear with thresholds or window type with which maximum or minimum values can be discriminated in addition to giving priorities to values that are close to the extreme values.

On the other hand, the information must be ordered before being used, this transformation applies the W_i values to the added value and independent of its original order.

Exposed the concept of OWA operators, it is considered not suitable for the treatment of the information that is intended. With which it is not taken into account in this presentation.

This allows considering the Weighted Averages, represented by Equation 1, as a viable alternative for the selection of resources. This statement is based on two particularities that it possesses, the first of which is the natural ordering of the terms X_n and the second, the possibility of valuing each term according to the interest it represents in the face of a stated objective.

6. Presentation of the models in the selection of suppliers

As in other areas, the selection of services and suppliers is based on the need to achieve a goal and from that, the alternatives to achieve it are presented. What is proposed for this section, is to present the application of the selection model based on AHP and to the Aggregation Operators through the Weighted Averages, so that they can be assessed in their development and results and from that point on to propose it as the base model for similar situations. Regarding the selection, the objectives can be as diverse as the needs that an organization could have for the development of its activities, especially those related to IT areas.

In order to limit this broad spectrum, it is possible to propose for the application of the methodology the objective of "selecting the IaaS provider whose resources will be used for a high-performance computation-oriented deployment with non-uniform workloads".

As mentioned earlier, the offer of cloud services leads to the proposal of a method of selecting resources that are offered by providers, in this particular case those that belong to the infrastructure service.

In the previous sections, models based on mathematical developments were presented that suggest being appropriate to address the selection of infrastructure service providers, in addition to presenting the results in a hierarchical manner.

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Accordingly, the following topics to be discussed will be the presentation of the main providers of IaaS, characteristics of the services they offer and the application of the methods presented.

6.1. IaaS providers

Today, online search services for infrastructure service providers currently respond to a specific number of those considered outstanding, particularly that they may have offices and support in the region. Although there are firms that offer third-party services, the decision was to have those that own their own infrastructure in order to obtain characteristics of reliable resources. On the other hand in (Mohammed & Kiran, 2015) they are presented to globally recognized IaaS providers that can be considered for the case. As expressed and suggested by (Mohammed & Kiran, 2015), they are presented as alternatives to IBM whose offices have been in Argentina for 95 years, AWS with support since 2017 in the region and RACKSPACE since 2015, as providers of IaaS to provide validity of the study. It is clear that in other regions there may be firms that provide support for infrastructure in the cloud, being presented hereinafter applicable to them. Below is a list with a description of these suppliers and their main service features.

IBM: it has two service models, the first is through the Bare Metal (BM) infrastructure, which is a dedicated physical server with hardware characteristics according to the business model. The second is through Virtual Servers (VS) where the physical hardware is shared and whose difference from the previous one is that it can contain several virtualized instances of servers. The services offered have the following characteristics:
Tenancy (T): single or BM, multiple or VS.
Billing (F): per hour or month.
Configuration options (O): all hardware in BM or CPU, RAM and storage in VS.
Computing power (P): 1 CPU with 4 cores to 4 CPUs with 12 cores in BM or more than 56 cores per VS.
Storage (A): up to 36 drivers for SSD 800GB to 1.2TB on BM or 25GB to 400GB provisioned by SSD on VS.
RAM (M): 3 TB on BM or up to 242GB VS.
Output bandwidth (BW): 10Gbps.
Input bandwidth: free.
Type of service: ideal for data intensive workloads that prioritize BM performance and reliability or highly variable workloads that prioritize flexibility and VS scalability.

These values were obtained from the provider's website https://www.ibm.com/cloud/infrastructure

AWS: it has two service models, the first is through the infrastructure dedicated hosts whose capabilities correspond to instances of services and the second is through VS. In general, the bases of the service model are differentiated by instances grouped by categories that are: general use, optimized for computing, optimized for memory, accelerated computing and optimized for storage. The services offered have the following characteristics:
Tenancy: dedicated physical hosts or virtual machines (MV).
Billing: monthly or the modality is the price per hour of use, except for those instances of contract on demand that allow setting the price per seconds (minimum of 60 seconds).
Configuration options: fixed by instances in both dedicated hosts and MV.
Computing power: from 20 to 224 physical cores and from 1 to 128 cores in MV.
Storage: from 475GB to 60000 GB in SSD NVMe (NVMe: new generation of SSD with PCI or M.2 connector).
RAM: from 166GB to 12TB.
Bandwidth: from 10 to 25Gbps with 14000Mbps (EBS: Excess Burst Size).
Type of service: instances of services grouped by qualities or capabilities.

These values were obtained from the provider's website https://aws.amazon.com/es/ec2/

RACKSPACE: It has two service models, the first is through the Bare Metal infrastructure (called On Metal) corresponds to a dedicated physical server distributed in 4 models. The second is through Virtual Servers

where the physical hardware is shared and whose difference with respect to the previous one is that it can contain several virtualized instances, it has 4 groups of options (for: general purpose, optimized for computing, optimized for data input / output and optimized in memory) in which each one has 4 presentations. The services offered have the following characteristics:
Tenancy: Single (BM) or multiple (VS).
Billing: per hour or month.
Configuration options: fixed by instances in both dedicated hosts and VS.
Computing power: 1 CPU with 6 cores to 2 CPU with 6 cores BM or from 2 to 32 vCPUs per VS.
Storage: 2x 240 GB (raid1 - mirror) SSD to 2x 1.6 TB PCIe storage devices in BM or from 20GB to 1.2TB on SSD provisioned in SV.
RAM: from 32GB to 128GB in BM or from 1GB to 240GB in VS.
Bandwidth: 10Gbps in BM or from 320Mbps to 10Gbps in VS.
Type of service: instances of services grouped by qualities or capabilities.

Values obtained from the provider's website https://www.rackspace.com/es-ar/library/what-is-iaas

It should be clarified that VMWARE was not taken into account within IaaS providers because the service it offers is that of software for cloud implementation and management.

6.2. Structuring of the hierarchical analytical process

According to the different steps of the model, it is necessary to establish the objective that represents the solution for the case study, the criteria for peer comparisons and the alternatives that will be evaluated, they are:

Goal: IaaS provider whose resources will be used for a high performance computing oriented implementation with workloads that are not uniform.
Criteria: The characteristics of Tenancy (T), Billing (F), Configuration Options (O), Computing power (P) and RAM (M) will be considered.
Alternatives: IBM, AWS and RACKSPACE.

6.2.1. Binary comparisons and weighing

After defining the criteria and alternatives, tables should be made for comparisons. They will contain the numerical value of the preference selected from Table I and the standardization for each element defined as criteria.

According to the characteristics that each supplier establishes for the Tenancy criteria, the comparison is made in Table 2 where the suppliers offer similar capabilities. Therefore, the value that results from the comparison alternatives has the numerical value "1" in all cells.

Tenancy	IBM	AWS	RACKSPACE
IBM	1	1	1
AWS	1	1	1
RACKSPACE	1	1	1
Total	3	3	3

Table 2. Pairwise comparison of the Tenancy criterion. Source: Self-made.

From the values obtained previously, the table of normalization of the elements of the cells must be formed and then obtain the arithmetic average of each line. Thus obtaining the value of the priority assigned to each alternative (provider) related to the criteria analyzed. It can be seen that, in the particular case of raising equal weight assignments, analog priority values are obtained (Table 3).

Tenancy	IBM	AWS	RACKSPACE	Priority
IBM	0,333	0,333	0,333	0,333
AWS	0,333	0,333	0,333	0,333
RACKSPACE	0,333	0,333	0,333	0,333

Table 3. Definitions of the priorities for the Tenancy criterion. Source: Self-made.

Based on what is expressed in (Medina, Cruz & Gomez, 2012), the evaluation of the congruence of the judgments that resulted in the valuation of the options should be considered in the development of the method.

For this it is necessary to resort to the analysis of consistency, from the normalized matrix, it will be considered consistent if the values of the cells of each column are equal. If the rule is not met, the degree of inconsistency must be determined. In the case of the Tenancy criterion, the columns of values of IBM, AWS and RACKSPACE have in each of their rows equal values, which has achieved consistency and, therefore, congruence.

According to the Billing options provided by the providers, it can be represented in Table 4 that both IBM and RACKSPACE offer the service with remuneration per month or hour, however AWS has a granularity in the time of use of capacity of measurement in seconds. This qualifies it as 'Very strongly / extremely preferable' compared to others, on the other hand, IBM and RACKSPACE are equally preferable.

Billing	IBM	AWS	RACKSPACE
IBM	1	0,125	1
AWS	8	1	8
RACKSPACE	1	0,125	1
Total	10	1,250	10

Table 4. Pairwise comparison of the Billing criterion. Source: Self-made.

When normalizing the values, Table 5 is obtained as a conclusion, where the priority found over the AWS provider over the Billing mode is higher than the others.

Billing	IBM	AWS	RACKSPACE	Priority
IBM	0,1	0,1	0,1	0,1
AWS	0,8	0,8	0,8	0,8
RACKSPACE	0,1	0,1	0,1	0,1

Table 5. Definition of priorities of the Billing criterion. Source: Self-made.

With respect to the criteria analyzed, the values obtained from normalization are the same in each row, which indicates congruence in the decision to assess the elements.

Based on the stated objective, whose required characteristics of Configuration Options make the weight values assigned to the suppliers in Table 6, IBM is preferable in a different way from the others.

Conf. Options	IBM	AWS	RACKSPACE
IBM	1	5	7
AWS	0,2	1	1
RACKSPACE	0,142	1	1
Total	1,342	7	9

Table 6. Pairwise comparisons for the Configuration Options criterion. Source: Self-made.

The weight values according to the preferences found mean that in Table 7 the priority found for IBM is far superior to the others.

Conf. Options	IBM	AWS	RACKSPACE	Priority
IBM	0,745	0,714	0,777	0,745
AWS	0,149	0,142	0,111	0,134
RACKSPACE	0,105	0,142	0,111	0,119

Table 7. Definition of priorities for the Configuration Options criterion. Source: Self-made.

The values obtained from the standardization of the Configuration Options criterion determine the existence of inconsistency, this results in the need to know what the degree of it is. In accordance with the aforementioned, the Consistency Index (CR) must be determined, if it is less than 0,1 it is considered "acceptable", otherwise, other values must be raised for the comparison of pairs that meet the aforementioned relationship. In this way:

$$RC = I_C / I_A < 0{,}1 \qquad (4)$$

Where:

$I_C = consistencyindex = (n_{max} - n)/(n-1)$

$I_A = randomconsistencyindex = (1{,}98 * (n-2))/n$

$n_{max} = \sum comparison\text{matrix} * priority\text{matrix}$

$n = \text{matrix}grade$

Applying the above equations it is obtained that RC = 0,006 < 0,1, therefore, the degree of inconsistency is acceptable and it is not necessary to modify the values of the comparison matrix.

Similar to the previous item, the definition of the objective aims to establish the values of preferences on suppliers for the Computation Power criterion. Table 8 reflects IBM's relationship with RACKSPACE that grants the 'Moderately Preferred' trial, followed by AWS's relationship with IBM that awards the 'Very Strongly Preferred' trial. The comparison of pairs and normalization are shown in Table 8 and Table 9.

Comp. Power	IBM	AWS	RACKSPACE
IBM	1	0,142	3
AWS	7	1	9
RACKSPACE	0,333	0,111	1
Total	8,333	1,253	13

Table 8. Pairwise comparison of the Computing Power criterion. Source: Self-made.

Comp. Power	IBM	AWS	RACKSPACE	Priority
IBM	0,12	0,113	0,23	0,153
AWS	0,84	0,798	0,692	0,744
RACKSPACE	0,039	0,088	0,076	0,067

Table 9. Definition of priorities for the Computing Power criterion. Source: Self-made.

Where the consistency ratio calculated from the preference values is RC = 0,066 <0,1, therefore the consistency is "acceptable".

In reference to the RAM Memory criteria and analyzing the different offers of the providers, it is shown in Table 10 that AWS predominates with respect to the others, it also reflects the minimum difference in the memory capacity offered by IBM with respect to RACKSPACE.

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RAM	IBM	AWS	RACKSPACE
IBM	1	0,142	3
AWS	7	1	9
RACKSPACE	0,333	0,111	1
Total	8,333	1,253	13

Table 10. Pairwise comparison and normalization for the RAM criterion. Source: Self-made.

With respect to Table 11, the superiority of AWS is noted due to the wide difference in priority over others.

RAM	IBM	AWS	RACKSPACE	Priority
IBM	0,105	0,101	0,166	0,124
AWS	0,842	0,809	0,75	0,8
RACKSPACE	0,052	0,089	0,083	0,074

Table 11. Definition of priorities for the RAM criterion. Source: Self-made.

With respect to this criterion, analyzing the values of the comparison matrix by pairs and the priorities, it is obtained that RC = 0,013 < 0,1 with which the degree of inconsistency is acceptable.

6.2.2. Comparison of peers and normalization of the Goal with respect to the Criteria

In this section, the comparison of pairs and the allocation of weight is carried out based on the preference over each criterion, the result of this is Table 12 where the computing power, memory and configuration possibilities predominate over the others for the statement raised in the objective.

Goal	T	F	O	P	M
T	1	1	0,25	0,125	0,125
F	1	1	1	0,25	0,333
O	4	1	1	0,25	0,25
P	8	4	4	1	1
M	8	3	4	1	1
Total	22	10	10,25	2,625	2,708

Table 12. Pairwise comparison of the Goal against the criteria. Source: Self-made.

From the assignments of the previous table, the normalization of the values is obtained obtaining Table 13.

Goal	T	F	O	P	M	Priority
T	0,045	0,1	0,24	0,047	0,046	0,0524
F	0,045	0,1	0,097	0,095	0,122	0,0918
O	0,181	0,1	0,097	0,095	0,092	0,113
P	0,363	0,4	0,39	0,38	0,369	0,38
M	0,363	0,3	0,39	0,38	0,369	0,36

Table 13. Priorities definitions of the Goal. Source: Self-made.

6.2.3. Evaluation of the alternatives

Once the assignments stage has been completed, it is necessary to evaluate the priorities, therefore it is necessary to select them one by one and add the results of the products between the priorities of the criteria and the objectives, which is represented by Equation 5.

$$ALT_i = \sum_{T}^{M} Prio(crit)_i * Prio(goal)_i \qquad (5)$$

The following hierarchy of the proposed alternatives is obtained from the evaluations:

IBM=0,333.0,0524+0,1.0,0918+0,745.0,113+0,153.0,38+0,124.0,36 = 0,213

AWS=0,333.0,0524+0,8.0,0918+0,134.0,113+0,744.0,38+0,8.0,36 = 0,677

RACKSPACE=0,333.0,0524+0,1.0,0918+0,119.0,113+0,067.0,38+ 0,074.0,36 = 0,0922

From the above, a hierarchy order can be established where the supply of resources and qualities of the AWS provider is superior to the others, with a score of 0,677 followed by IBM and RACKSPACE.

6.3. Structuring the aggregation model

From the above on this model, it should be noted that the structure for its development consists in determining the criteria that will be evaluated, followed by establishing a weight or qualification of importance to each of them taking into account an objective.

Accordingly, it is considered appropriate that the characteristics of IaaS providers be taken as criteria to be evaluated. Here is the situation where those of Tenancy, Billing and Configuration Options do not have amounts to be represented, for this the solution that is proposed in cases where a response can be true or false is to represent these statements with 1 (one) and 0 (zero) respectively, analogously to what is stated in the influence matrix proposed by the Network Analytical Process (ANP) from (Guerrero-Liquet & Faxas-Guzmán, 2015) (Sampedro-Durá, Puchol-García & Aragonés-Beltrán, 2011).

In this way, Table 14 and the standardized values can be made in Table 15.

Supplier / Criteria	T	F	O	P (CPU)	A (GB)	M (MB)	BW (Gbps)
IBM	1	0	1	56	1200	242	10
AWS	1	1	0	128	60000	12000	25
RACKSPACE	1	0	0	32	1600	240	10
Total	3	1	1	216	62800	12482	45

Table 14. Quantities by criteria. Source: Self-made.

Supplier / Criteria	T	F	O	P	A	M	BW
IBM	0,333	0	1	0,259	0,019	0,019	0,222
AWS	0,333	1	0	0,592	0,955	0,961	0,555
RACKSPACE	0,333	0	0	0,148	0,025	0,019	0,222
Total	1	1	1	1	1	1	1

Table 15. Standardization of criteria. Source: Self-made.

It remains to give treatment to the vector of weights and the normalization of their values, respecting the slogan "select the provider of IaaS whose resources will be used for a deployment oriented to high performance computing with non-uniform workloads" and assessing the preference among criteria The foregoing is represented in Table 16 and Table 17 where preference is accentuated in the Computation Power and RAM Memory criteria.

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T	F	O	P	A	M	BW	Total
4	4	6	8	3	8	3	36

Table 16. Weighting on criteria. Source: Self-made.

T	F	O	P	A	M	BW	Total
0,111	0,111	0,166	0,222	0,083	0,222	0,083	1

Table 17. Normalization of the vector of weights. Source: Self-made.

Obtained the values that represent the characteristics offered by the suppliers and the weights assigned to them, it remains to apply (1) for each of the suppliers, where:

IBM=0,333.0,111+0.0,111+1.0,166+0,259.0,222+0,019.0,083+0,019.0,222+0,222.0,083 = 0,284

AWS=0,333.0,111+1.0,111+0.0,166+0,592.0,222+0,955.0,083+0,961.0,222+0,555.0,083 = 0,618

RACKSPACE=0,333.0,111+0.0,111+0.0,166+0,148.0,222+0,0255.0,083+0,019.0,222+0,222.0,083 = 0,094

Where you can establish a hierarchy order in which the offer of resources and qualities of the AWS provider is superior to the others, with a score of 0,618 followed by IBM and RACKSPACE.

7. Comparison of results and development

From the results obtained in both methods, which are represented in Table 18, it can be affirmed that there is a minimal difference between the values found for the suppliers with the AHP methods and Aggregation Operators. Another observation that merits exposure is the complexity in the developments of both, whose summary is presented in Table 19.

Supplier / Method	AHP	Weighted averages
IBM	0,213	0,284
AWS	0,677	0,618
RACKSPACE	0,0922	0,09

Table 18. Results comparison. Source: Self-made.

With respect to the comparison in the development of both methods, it is clear that the AHP requires more work to obtain a result with respect to the one proposed by Powered Stockings that is reflected in the amount of tables to be made. The marked difference is due to the fact that AHP is based on valuations made by the decision maker between criteria and between alternatives, while the proposal uses magnitudes characteristic of the characteristics of the criteria that are then qualified to align with the objective.

To compare / Method	AHP	Weighted averages
Number of stages	3 (evaluation of criteria, evaluation of alternatives and evaluation)	3 (quantification of criteria, assessment and evaluation)
Number of tables	12	4
Based on	Comparison and assessment of criteria and alternatives	Assessment on quantities described by the criteria
Support	Mathematical	Mathematical

Table 19. Development comparison. Source: Self-made.

8. Conclusions

Cloud computing is a technology whose offer of resources makes it very attractive for organizations. The providers of this technology offer a variety of resources for the SaaS, PaaS and IaaS models, each of which, according to the degree of functionality desired, can be accessed free of charge or in a paid way through a service contract.

As for the resources that are available for the IaaS model, servers with BM or VS options along with the memory and processing capabilities, can be considered as key requirements to address high-performance computing with CC technologies.

It is essential to know the models for the treatment of information in order to select suppliers or resources in an appropriate way. Among a wide variety of options, those who have a mathematical development have the quality of being precise and away from the ambiguities of selection that those based on the comparison of resources might have. The aggregation operators arise as a tool that allows combining data that comes from suppliers with preferences of the decision maker, allowing to obtain a result that meets the needs, this by assigning a greater weight to the criteria that requires it.

In reference to the example presented, the characteristics of resources offered by the AWS provider are suitable for the proposed objective, being able to verify for both selection methods, however this could be different if the needs were different because the weights would be accentuated over other criteria.

In addition to the comparison of those, it is possible to affirm that the Weighted Averages presents a reduced development with respect to AHP, the results being similar, it follows that the aggregation method presented is a viable alternative that must be taken into account for similar tasks. to the example.

From the above, it is necessary that the organization's ICT staff possesses the knowledge of its infrastructure and the alternatives that cloud computing can offer, in order to select the criteria in an appropriate way according to the needs of each activity.

For complex situations where the requirements are high, it will be necessary to modify the proposed criteria and the number of them in order to improve the degree of certainty in the selection of resources.

With regard to the selection of resources in general, taking into account SaaS, PaaS and IaaS, the application of the proposed methodology would be implemented through the same stages, however, the change would be given by prioritizing the criteria according to the required needs about each model.

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