BIG DATA MINING AND ANALYTICS
ISSN 2096-0654 02/10 pp127–138
Volume 6, Number 2, June 2023
DOI: 10.26599/BDMA.2022.9020016

Cloud-Based Software Development Lifecycle: A Simplified Algorithm for Cloud Service Provider Evaluation with Metric Analysis

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Abstract: At present, hundreds of cloud vendors in the global market provide various services based on a customer's requirements. All cloud vendors are not the same in terms of the number of services, infrastructure availability, security strategies, cost per customer, and reputation in the market. Thus, software developers and organizations face a dilemma when choosing a suitable cloud vendor for their developmental activities. Thus, there is a need to evaluate various cloud service providers (CSPs) and platforms before choosing a suitable vendor. Already existing solutions are either based on simulation tools as per the requirements or evaluated concerning the quality of service attributes. However, they require more time to collect data, simulate and evaluate the vendor. The proposed work compares various CSPs in terms of major metrics, such as establishment, services, infrastructure, tools, pricing models, market share, etc., based on the comparison, parameter ranking, and weightage allocated. Furthermore, the parameters are categorized depending on the priority level. The weighted average is calculated for each CSP, after which the values are sorted in descending order. The experimental results show the unbiased selection of CSPs based on the chosen parameters. The proposed parameter-ranking priority level weightage (PRPLW) algorithm simplifies the selection of the best-suited cloud vendor in accordance with the requirements of software development.

Key words: cloud-based software development life cycle (SDLC); cloud evaluation; parameter-ranking priority level weightage (PRPLW) algorithm; cloud service providers; software engineering

1 Introduction

1.1 Cloud computing environment

There have been many improvements since the introduction of the cloud computing concept. Most users and organizations are interested in the cloud computing model for their business activities, and software developers and their organizations are not an exception in this case. Nowadays, users and organizations, do not face a dilemma on whether to choose cloud or on-premise resources.

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Manuscript received: 2022-04-05; Revised: 2022-05-30; Accepted: 2022-06-20

In this study, we analyzed the significant challenges of software development in a cloud environment[1] and developed a cloud-based software development life cycle model as shown in Fig. 1[2], thus helping developers to utilize the model as a framework for cloud-based developmental activities. The major challenges in selecting the cloud service providers (CSPs) are as follows: (1) the metrics to be considered for CSP selection, (2) the various services offered by CSPs, and (3) the process of choosing the best, most suited CSP from the numerous cloud vendors existing in the global market.

1.2 CSPs

There are numerous CSPs across the globe with different services, pricing models, and infrastructures. The list of major CSPs across the globe is shown in Table 1.

As per Gartner's Magic Quadrant for Cloud

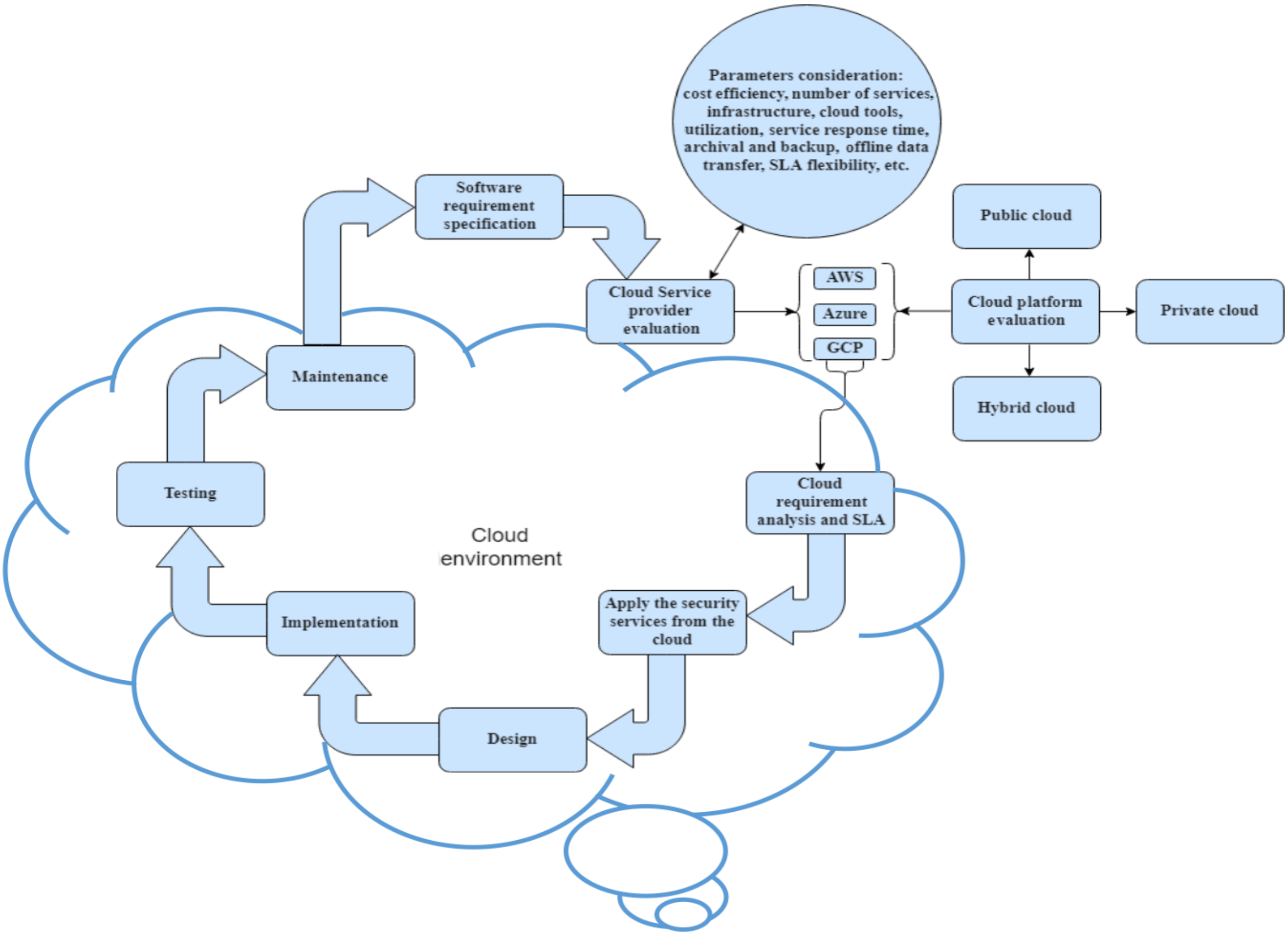

Fig. 1 Design of cloud-based software development life cycle (SDLC).

Table 1 Major service providers in the global market of cloud.

Serial No.	Cloud service provider
1	Amazon web service (AWS)
2	ServerSpace
3	Microsoft Azure
4	Google Cloud Platform (GCP)
5	IBM Cloud Services
6	Adobe Creative Cloud
7	Kamatera
8	VMware
9	Rackspace
10	Red Hat
11	Salesforce
12	Oracle Cloud
13	SAP
14	Verizon Cloud
15	Navisite
16	Dropbox

Infrastructure and Platform Services published in 2021[3], as shown in Fig. 1, the top three CSPs are:

(1) Amazon Web Services (AWS),

(2) Microsoft Azure,

(3) Google Cloud Platform (GCP).

Once the top three vendors are identified, the primary goal is to choose the most appropriate one among them for a software requirement specification.

1.3 Motivation

• Most of the existing solutions and methods talk about simulation tools for choosing service providers, and there is no clear comparison of services from top vendors to allow prospective users to choose the particular services they need while developing their software products.

• Cost comparisons of the main CSPs and their various pricing models are not available, furthermore these metrics cannot be found in one place.

• Major existing solutions prefer to rank cloud vendors based on quality of service (QoS) attributes such as performance, throughput. Although the QoS attributes play a vital role, the competing vendors may have performance variation of $\pm 5\%$ which should not cost the precious time of developers.

1.4 Main contribution

• This work clearly gives the comparison of various services offered, the costs involved, infrastructure requirements, various tools offered as a service, and information about service availability and non-availability with respect to three cloud vendors for the evaluation of the cloud by the developers, along with the advantages and disadvantages of individual cloud vendors.

• A simplified algorithm named parameter-ranking priority level weightage (PRPLW) algorithm is proposed to help developers choose the most suitable CSP from the given choices.

• The proposed algorithm has been proven to work based on the parameter ranking and weightage allocated and the priority level weightage allocated after a thorough analysis of parameters.

2 Review of the Literature

The selection of the best and most suitable CSP from multiple vendors based on the specifications and requirements is a challenging task for cloud users[4]. Upadhyay et al.[4] proposed a systematic QoS evaluation and ranking framework for the cloud environment which evaluated cloud vendors in terms of multiple qualitative and quantitative data and ranked them. The major drawback is that collecting previous data for evaluation purposes takes a longer time.

Meanwhile the cloud services trust evaluation model (CSTEM) has been proposed to gain the trust of the users concerning security-related issues in the cloud and to improve the reputation of an organization[5]. The proposed model, however, has the following limitations.

(1) The dynamic update factors must be considered for cloud evaluation to improve the CSTEM model;

(2) The security services and performance metrics have to be thoroughly experimented with, to improve the interaction success rate.

Wibowo et al.[6] proposed a performance evaluation method named the "fuzzy multicriteria group decision-making method" for cloud services. The interval-valued intuitionistic fuzzy numbers are used to model the evaluation process. Although this method proved to be an efficient model for ranking the service provider, it is limited only to evaluating performance metrics.

A previous study introduced a QoS-aware selection model that developed a three-level representation scheme for systematically and succinctly representing QoS attributes[7]. Compared to other existing methods, this framework fetches information from multiple sources such as information from cloud vendors, performance monitoring data collected from multiple third-party tools, and more relevant reviews from users. The collected information from various sources helps in improving the selection process of cloud vendors. The model, however, does not provide any information about the various services offered by the vendors and the selection process only depends on performance and reviews.

Reference [8] used a neo-institutional lens and adopted several strategies (i.e., efficiency-motivated adoption, non-adoption, and legitimacy-motivated adoption) to understand the internal and external factors that impact adopting cloud computing. The work is limited to a specific country and only considers factors that are limited to a particular region. Thus, more detailed research may be considered to deal with individual factor analysis, and different countries also need to be examined.

Reference [9] proposed a method called "cloud service research and selection system" (CSRSS), which selects the service provider concerning QoS attributes specified as per the requirements. Here the user must specify the QoS attribute values depending on the requirements, although the proposed method lacks the ability to choose the services required, and does not provide a cost estimation.

Finally, Ref. [10] proposed a model whose design is based on the client-CSP relationship. The three major factors considered in choosing the CSP are client satisfaction, relationalism, and dependence. The model was tested for one particular context, and the simulation results were satisfactory. The model must be studied in terms of multiple contexts, and the results have to be further analyzed, especially the boundary conditions for the proposed model.

3 Challenge

Based on the review of literature, different cloud computing adoption techniques face different challenges especially the data collection process, the simulation tool-based selection of cloud vendors, and the comparison of the current services offered, cost per customer, tools required, and so on. When the QoS attributes are considered for evaluating the cloud vendor, the performance may vary by $\pm 5\%$, which can be maximized by using high-capacity instances. The major challenges to be addressed for a user to choose the CSP are as follows:

(1) The simplest algorithm to be followed while choosing the CSP;

(2) The metrics to be considered for evaluating the CSP and their visibility to the evaluator;

(3) Various features available from the vendors and their pricing models; and

(4) A comparative study of different vendors based on the metrics chosen.

4 Comparative Study of the Top Three Cloud Vendors

The identified top three cloud vendors were analyzed based on the selected metrics, including cloud establishment, services offered, key tools offered as part of the services, cloud platform, and pricing models. These basic metrics allow prospective users to assess the vendors and choose the most suitable for them in terms of software specification and development requirements.

4.1 Metrics for comparison

4.1.1 Cloud establishment and market share

Amazon web services is a pioneer in the area of cloud computing and is an experienced service provider in the market. AWS has major clients using its services with trust and satisfaction.

Initially, AWS launched cloud services for its e-commerce business purpose. Later in the year 2006 it started providing services publicly with major services offered in the categories of infrastructure such as virtual machines (EC2), storage options (Amazon S3), etc. From 2009 onwards it introduced additional services, such as Elastic Block Store, Amazon CloudFront, AWS Route 53, and AWS notification and messaging services. AWS currently holds a 32% market share across the globe and is considered the top-ranked CSP in the market share chart.

Microsoft Azure initially started with the name “Azure” in 2010. This CSP aims to provide various cloud-based services from Microsoft to any other businesses. In 2014, it was renamed “Microsoft Azure”. From the time of its introduction, it has shown a very good progress rate and competitive advantage. Currently, Azure has 19% of the global market share.

Google cloud platform started its cloud services in 2011. In just ten years, it has grown to become the top three global CSP and has created an impact in the market. Initially this service was launched to expand the infrastructure to support YouTube and Google’s search engine. GCP currently has 7% of the global market share.

4.1.2 Cloud services

The cloud providers offer a variety of services and are broadly categorized as computing, storage, database, and networking services[11]. The comparison of services offered by the top three cloud vendors namely AWS[12], Azure[13], and GCP[14], for these categories are shown in Tables 2–5.

By considering the overall services, AWS, Azure, and

Table 2 Computing services.

Cloud service	Amazon web services	Microsoft Azure	Google cloud platform
Infrastructure as a service	Amazon EC2 (Elastic Compute Cloud)	Virtual machines	Google Compute Engine
Platform as a service	AWS Elastic Beanstalk	App service and cloud services	Google App Engine
Container options	Amazon EC2 Container Service	Azure Kubernetes Service (AKS)	Google Kubernetes Engine
Serverless functionality	AWS Lambda	Azure Functions	Google Cloud Functions

Table 3 Database services.

Cloud service	Amazon web services	Microsoft Azure	Google cloud platform
Relational database management system	Amazon Relational Database Service	SQL database	Google Cloud SQL
NoSQL: key–value	Amazon DynamoDB	Table storage	Google Cloud Datastore Google Cloud Bigtable
NoSQL: indexed	Amazon SimpleDB	Azure Cosmos DB	Google Cloud Datastore

Table 4 Storage services.

Cloud service	Amazon web services	Microsoft Azure	Google cloud platform
Object storage	Amazon Simple Storage Service	Blob Storage	Google Cloud Storage
Virtual server disks	Amazon Elastic Block Store	Managed disks	Google Compute Engine Persistent Disks
Cold storage	Amazon Glacier	Azure Archive Blob Storage	Google Cloud Storage Nearline
File storage	Amazon Elastic File System	Azure File Storage	ZFS/Avere

Table 5 Networking services.

Cloud service	Amazon web services	Microsoft Azure	Google cloud platform
Virtual network	Amazon Virtual Private Cloud (VPC)	Virtual Networks (VNets)	Virtual private cloud
Elastic Load balancer	Elastic Load Balancer	Load Balancer	Google Cloud Load Balancing
Peering	Direct Connect	ExpressRoute	Google Cloud Interconnect
Domain name system	Amazon Route 53	Azure DNS	Google Cloud DNS

the GCP provide approximately 200+, 100+, and up to 60+ cloud services, respectively.

4.1.3 Key cloud tools

All three CSPs face huge competition in providing cloud-based tools to end-users. For the current industry needs and customer requirements, several tools are offered as services[15] by the three vendors, as shown in Table 6.

4.1.4 CSP pricing models

The three CSPs use various pricing models to satisfy user needs. A comparison of their pricing models is presented in Table 7.

The comparison shown in Table 8 provides insights into pricing models for the virtual machine types[16] of AWS, Azure, and GCP.

4.2 CSPs: Pros and Cons

Table 9 provides insights into the advantages and disadvantages of the top three major cloud vendors based on the analysis of metrics considered in the current work.

5 Comparison of Availability and Non-Availability of Services from Vendors

It is very important for software developers to know which services are required for their development activity and at which particular period of the development plan they will be used. Therefore, the developer must check for the availability of such services required for development from the chosen vendor. Table 10 provides insights into the available (marked as $\surd$) and non-available (marked as $\times$) services from

Table 6 Comparison of tools from various cloud vendors.

Cloud tools	Artificial intelligence and machine learning	Internet of things	Serverless functionality
Amazon Web Services	(1) Tensorflow on AWS, Apache MXNet on AWS (2) Sagemaker, Deep learning Amazon Machine Images, DeepLens (3) Transcribe, Translate, Machine Learning (4) Rekognition, Polly, Lex, Comprehend	(1) IoT Device Management (2) Greengrass (3) IoT Button (4) IoT Device Defender (5) IoT Analytics (6) FreeRTOS (7) IoT Core (8) IoT 1-click	(1) Lambda (2) Serverless Application Repository
Microsoft Azure	(1) Cognitive Services (2) Machine Learning (3) Azure Bot Service	(1) Time Series Insights (2) IoT Edge (3) Stream Analytics (4) IoT Hub	Functions
Google Cloud Platform	(1) Cloud Job Discovery (Private Beta), Cloud Video Intelligence, Cloud Translation API, Cloud Speech API (2) Dialogflow Enterprise Edition, Cloud Natural Language (3) Cloud Machine Learning Engine	Cloud IoT Core (Beta)	Cloud Functions (Beta)

Table 7 Pricing models of the top three CSPs.

Cloud service provider	Pricing	Model
AWS	Per hour (rounded up) Per minute (rounded up)	On-demand, spot, reserved
Azure	Per minute (rounded up) Prepaid type or monthly billing	On-demand (short-term) Prepaid type or monthly billing
GCP	Per minute (rounded up, minimum 10 mins) Per second (rounded up)	On-demand (sustained use)

Table 8 Pricing models of the top three CSPs at the virtual machine level.

Virtual machine type	AWS	Azure	GCP
Smallest instance	vCPUs: 2 RAM: 8 GB Cost: USD 69 per month	vCPUs: 2 RAM: 8 GB Cost: USD 70 per month	vCPUs: 2 RAM: 8 GB Cost: USD 52 per month
Largest instance	vCPUs: 128 RAM: 3.84 TB Cost: USD 3.97 per hour	vCPUs: 128 RAM: 3.89 TB Cost: USD 6.79 per hour	vCPUs: 160 RAM: 3.75 TB Cost: USD 5.32 per hour

Table 9 Pros and cons of top three cloud vendors.

Cloud service providers	Pros	Cons
Amazon web services	(1) Oldest and strongest hold in the cloud market (2) Extensive and mature service offerings (3) Support for large-scale organizations as the leader in infrastructure (4) Provides necessary training to customers (5) Higher reachability across the globe	(1) Little difficulty for customers to use (2) Managing the cost per customer (3) Multiple services and varieties of options are available, so searching for suitable services can be challenging
Microsoft Azure	(1) Top two ranked CSP (2) Easy to integrate the software and tools with Microsoft products (3) Broad feature set (4) Open-source support	(1) The documentation process has issues (2) The tools for managing the services are insufficient
Google Cloud Platform	(1) Cost-efficient infrastructure service (2) Option for portability (3) Open source support (4) Flexibility in agreements and discount offers. (5) Expertise in development and operations	(1) Late entry to the cloud market compared to other top vendors (2) Less number of services offered (3) Infrastructure used is the same as the Google search engine and YouTube facility.

the three major cloud vendors.

6 PRPLW-Based CSP Selection Algorithm

Based on the analysis with respect to metrics or parameters considered, such as establishment, services, infrastructure, tools, pricing models, and current market share, the three CSPs are ranked against each metric or parameter and assigned a weightage, as shown in Table 11. The parameter-ranking and weightage assigned are represented in graphic format in Fig. 2.

- Establishment. AWS is ahead of any other CSPs as it is the pioneer in the industry.
- Infrastructure. For infrastructure, AWS clearly stands tall as it has more regions and availability zones.
- Market share. Having 32% of the global share in the cloud market, AWS has the upper hand.
- Growth rate. Comparatively, GCP is growing faster by almost 100%.
- Utilization. Most of the major customers of the cloud are using the top three CSPs almost equally.
- Services.
  - Considering the overall services offered, AWS offers 200+ services compared to Azure or GCP.
  - For the integration of services, such as Microsoft products with on-premise systems and open-source software, Azure is the better option.
- Pricing models and cost efficiency. Based on user-friendly pricing models and the deep discounts offered to the user, the GCP is a better choice.
- Reputation. Based on the market share, brand name, and utilization, AWS has the upper hand.
- Storage service options.
  - AWS provides three storage types (object, block, and file storage).
  - Azure provides only two types of storage (object and file storage).
  - GCP provides only two types of storage (object and block storage).
- Archival and backup. AWS and Azure provide archival storage with lifecycle management, whereas GCP does not have this option.
- Offline data transfer. AWS leads with mobile devices for offline transfer of data.

As far as the remaining parameters (e.g., availability, disaster recovery, cloud tools, accountability, service response time, etc.) are concerned, all the three CSPs are equally competent.

The parameter selection for individual projects differs

Table 10 Comparison of the availability and non-availability of services offered by the top three CSPs.

Cloud service	Amazon web service	Microsoft Azure	Google cloud platform
Regions and availability zones	√	√	√
Various pricing models	√	√	√
Virtual machines for computing purpose	√	√	√
Containers services	√	√	√
Serverless functionality	√	√	√
Mobile app hosting service on the cloud	√	√	√
Batch processing service	√	√	×
Object storage	√	√	√
Block storage	√	×	√
File storage	√	√	×
Hybrid storage	√	√	×
Offline data transfer	√	×	√
Relational database service	√	√	√
NoSQL database	√	√	√
In-memory database	√	√	×
Archival data and backup service	√	√	√
Disaster recovery management	√	√	×
Machine learning tools and services	√	√	√
Cognitive services	√	√	√
IoT tools and resources service	√	√	√
Networking services	√	√	√
Content delivery network services	√	√	√
Big data analytics services	√	√	√
Identity access management and authentication service	√	√	√
Cloud security services	√	√	√
Application lifecycle management	√	√	×
Cloud monitoring and management	√	√	√
AR & VR service	√	√	√
VPC on public cloud	√	×	√
Customer training service	√	√	√
Customer support service	√	√	√
Third-party software as a service	√	√	√

from one another. Each parameter contributes to the project and has its own priorities. The weightage of less prioritized parameters should not influence the selection of CSPs. Thus the parameters are categorized into three priority levels (highest to lowest) and assigned constant weightage based on the priority, as shown in Table 12.

In this study, the PRPLW algorithm is developed for the selection of a suitable CSP based on the requirements of the software to be developed by considering the parameters, rankings, and weightages in Tables 11 and 12. The process diagram for the PRPLW-based CSP selection algorithm (Algorithm 1) is shown in Fig. 3.

Before choosing the CSP, the software development team must have the software requirement specifications and the important parameters concerning cloud-based development activities as inputs to the algorithm.

The selected parameters from the user are categorized as priority level 1 (PL1), priority level 2 (PL2), and priority level 3 (PL3) based on Table 12 and the values for n_1, n_2, and n_3 are determined (Number of parameters in each category). The weightage will be assigned to each level. Then the weighted average for each CSP is calculated separately. The obtained weighted average values are sorted in descending order and then ranked. The top-ranked CSP shall be suggested as the suitable CSP based on the chosen parameters.

6.1 Sample experimentations and results

The parameters are selected by the developer based on the requirements specifications. These parameters are categorized in accordance with priority levels and weightage allocated, as shown in Table 12. Based on the

Table 11 Parameter-based ranking and weightage of the CSP selection.

Parameter	Ranking			Weightage*		
	AWS	Azure	GCP	AWS	Azure	GCP
Establishment	1	2	3	1	0.75	0.5
Infrastructure	1	2	3	1	0.75	0.5
Number of services	1	2	3	1	0.75	0.5
Utilization	1	2	3	1	0.75	0.5
Pricing models and cost efficiency	2	3	1	0.75	0.5	1
Storage service options	1	2	3	1	0.75	0.5
Service response time	1	1	1	0.75	0.75	0.75
Accountability	1	1	1	0.75	0.75	0.75
Availability	1	1	1	0.75	0.75	0.75
Cloud tools	1	1	1	0.75	0.75	0.75
Archival and backup	1	2	3	1	0.75	0.5
Market share	1	2	3	1	0.75	0.5
Growth rate	3	2	1	0.5	0.75	1
Offline data transfer	1	2	3	1	0.75	0.5
Disaster recovery	1	1	–	0.75	0.75	0
SLA flexibility	1	1	1	0.75	0.75	0.75
Compatibility with Microsoft products	2	1	3	0.75	1	0.5
Reputation	1	2	3	1	0.75	0.5

Note: Weightage is assigned for each parameter of CSP based on the ranking as follows: 1 for rank 1, 0.75 for rank 2, and 0.5 for rank 3.

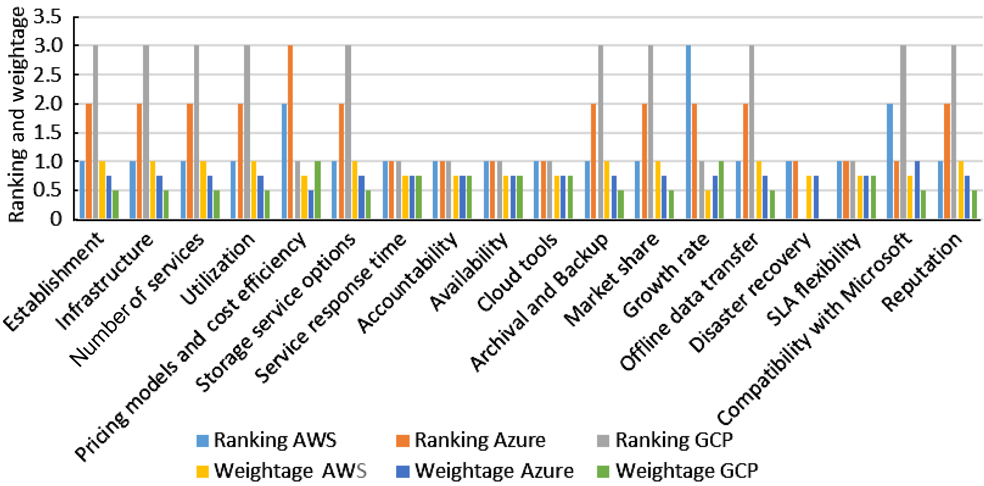

Fig. 2 Parameter-ranking and weightage.

parameter weightage and priority level weightage, the weighted average for each CSP is calculated separately and then sorted in descending order. The highest weighted average CSP is the suggested CSP for the chosen parameters.

6.2 Experiment 1

• Step 1. Display parameters: pricing models and cost efficiency, infrastructure, wide range of services, service response time, accountability, availability, archival and backup, SLA flexibility, storage service options, offline data transfer, disaster recovery, cloud tools, utilization, reputation, establishment, market share, and growth rate.

• Step 2. Input parameters: cost efficiency, infrastructure, availability, SLA flexibility, utilization, growth rate.

• Step 3. Categorization. PL1 category: cost efficiency, infrastructure, availability, SLA flexibility ($n_1 = 4$); PL2 category: utilization ($n_2 = 1$); PL3 category: growth rate ($n_3 = 1$).

• Step 4. Assigning weightage to the following categories: $PL_1 = 0.5$, $PL_2 = 0.3$, $PL_3 = 0.2$.

• Step 5. Calculation of the weighted average using

Table 12 Priority level categories and weightage.

Parameter	Priority level	Weightage
Pricing models and cost efficiency Infrastructure Wide range of services Service response time Accountability Availability Archival and Backup SLA flexibility	PL1 (High)	0.5
Storage service options Offline data transfer Disaster recovery Compatibility with Microsoft products Cloud tools Utilization	PL2 (Medium)	0.3
Reputation Establishment Market share Growth rate	PL3 (Low)	0.2

the following equations.

$$P_{\text{AVG, AWS}} = \left(\frac{3.25}{4}\right)\times 0.5+\left(\frac{1}{1}\right)\times 0.3+\left(\frac{0.5}{1}\right)\times 0.2 = 0.806\,25$$

$$P_{\text{AVG, AZ}} = \left(\frac{2.75}{4}\right)\times 0.5+\left(\frac{0.75}{1}\right)\times 0.3+\left(\frac{0.75}{1}\right)\times 0.2 = 0.718\,75$$

$$P_{\text{AVG, GCP}} = \left(\frac{3}{4}\right)\times 0.5+\left(\frac{0.5}{1}\right)\times 0.3+\left(\frac{1}{1}\right)\times 0.2 = 0.725$$

• Step 6. Sorting the weighted average values and ranking, as shown in Table 13.

• Step 7. Output: the top-ranked AWS is suggested as the suitable CSP based on the chosen parameters for development. The graphical representation of the results is shown in Fig. 4.

As shown in the example, the chosen parameters by the developer are infrastructure, availability, and cost efficiency. The results show that AWS provides better infrastructure compared to any other service provider, with an availability of 99.99%. As per the weighted average calculation, the AWS cloud is thus suggested for the developer.

6.3 Experiment 2

In this experiment, the input parameters are compatibility with Microsoft products, disaster recovery, service response time, cloud tools, availability, SLA flexibility, utilization, and growth rate. The calculation of this and the following experiments is similar to that of Experiment 1.

The PRPLW algorithm sorted the weighted average values and ranking, as shown in Table 14.

In this experiment, he top-ranked Azure Cloud is suggested as the suitable CSP based on the chosen parameters for development. The graphical representation of the results is shown in Fig. 5.

The parameters selected are compatibility with Microsoft products, disaster recovery, service response time, cloud tools, availability, SLA flexibility, utilization, and growth rate. The compatibility for Microsoft products is provided by Azure Cloud without additional configurations, while some of the parameters have the same (or less) priority. Thus, Azure is the most suitable CSP for this user.

6.4 Experiment 3

In this experiment, the input parameters are cost efficiency, storage service options, cloud tools, accountability, SLA flexibility, and growth rate.

The PRPLW algorithm sorted the weighted average values and ranking, as shown in Table 15.

In this experiment, the top-ranked GCP is suggested as the suitable CSP for this user based on the chosen parameters for development. The graphical representation of the results is shown in Fig. 6.

When the cost is the major factor compared to any parameters, the Google Cloud Platform is the best-suited cloud provider. The developer has chosen the cost parameter along with other parameters which are having common priority. So the Google Cloud Platform is the

Algorithm 1　PRPLW-based CSP selection algorithm

Input: P_i, the important parameters pertaining to software development.

Output: P_o, the suitable CSP as per the requirements and parameters.

Function: Selection of CSP

1: Display the parameters for consideration as per the software requirements specification (SRS).

2: Input the various parameters chosen for software development.

3: Categorize the parameters as per the following priority levels: n_1 as number of parameters in the PL1 category, n_2 as number of parameters in the PL2 category, and n_3 as number of parameters in the PL3 category.

4: Assign weightage for each priority ($PL_1 = 0.5, PL_2 = 0.3, PL_3 = 0.2$).

5: Calculate the weighted average for the individual CSPs using the following equation.

$$P_{\text{AVG, AWS}} = \sum_{i=1}^{n_1}(P_{i,\text{AWS}}/n_1) \times PL_1 + \sum_{i=1}^{n_2}(P_{i,\text{AWS}}/n_2)\times PL_2 + \sum_{i=1}^{n_3}(P_{i,\text{AWS}}/n_3) \times PL_3 \tag{1}$$

$$P_{\text{AVG, AZ}} = \sum_{i=1}^{n_1}(P_{i,\text{AZ}}/n_1) \times PL_1 + \sum_{i=1}^{n_2}(P_{i,\text{AZ}}/n_2)\times PL_2 + \sum_{i=1}^{n_3}(P_{i,\text{AZ}}/n_3) \times PL_3 \tag{2}$$

$$P_{\text{AVG, GCP}} = \sum_{i=1}^{n_1}(P_{i,\text{GCP}}/n_1) \times PL_1 + \sum_{i=1}^{n_2}(P_{i,\text{GCP}}/n_2)\times PL_2 + \sum_{i=1}^{n_3}(P_{i,\text{GCP}}/n_3) \times PL_3 \tag{3}$$

6: Sort the weighted average values in ascending order.

7: Output the rank as per the sorted order and suggest the top rank as the suitable CSP based on the chosen parameters.

most suitable cloud provider.

6.5　Experiment 4

In this experiment, the input parameters are cost efficiency, reputation, establishment, market share, and growth rate.

The PRPLW algorithm sorted the weighted average values and ranking, as shown in Table 16.

In this experiment the top-ranked GCP is suggested as the suitable CSP in this case based on the chosen parameters for development. The graphical representation of the results is shown in Fig. 7.

The parameters chosen are cost efficiency, reputation, establishment, market share, growth rate. All the parameters except cost suggest the AWS cloud based on the parameter ranking, which is a biased result. When it comes to cost, the GCP is the most cost-efficient cloud provider. The priority level and weightage allocation thus come into the picture to obtain an unbiased result. Nevertheless, the weighted average calculation suggests GCP as the most suitable CSP.

The experimentation results show the selection of CSPs based on the parameters chosen for development using the PRPLW based CSP selection algorithm. The experiment results are available for each CSP, and one result is shown for an unbiased CSP selection.

7　Conclusion and Future Work

Considering the above analysis, an important and challenging task in the process of selecting the CSP for any software development activities on the cloud has been simplified using the proposed PRPLW based CSP selection algorithm. By analyzing the parameters with the comparative study for all three CSPs, along with their ranking and allocated weightage a development team can choose the parameters that have an impact on software development activities from the set of parameters listed. The proposed algorithm shows unbiased results, as the introduction of priority level weightage removes any such bias. The experimentation results reveal that the process of CSP selection is simplified and takes less time to decide on selection. Thus, the developer can select

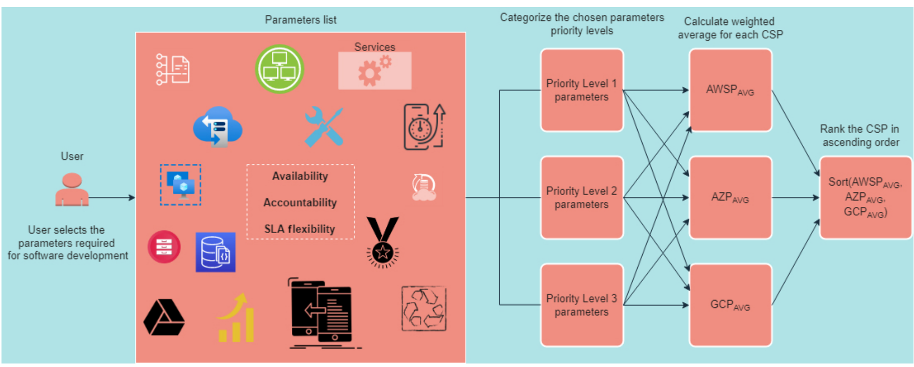

Fig. 3　Process diagram for the PRPLW-based CSP selection algorithm.

Table 13 Weighted average values and ranking in Experiment 1.

Ranking	Sorted value	Cloud service provider
1	0.806 25	Amazon Web Services
2	0.725	Google Cloud Platform
3	0.718 75	Azure Cloud

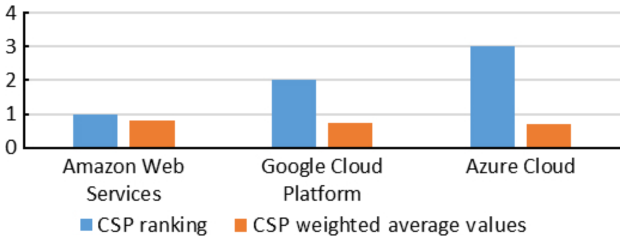

Fig. 4 Experiment 1 results.

Table 14 Weighted average values and ranking in Experiment 2.

Ranking	Sorted value	Cloud service provider
1	0.852 08	Azure Cloud
2	0.843 75	Amazon Web Services
3	0.747 91	Google Cloud Platform

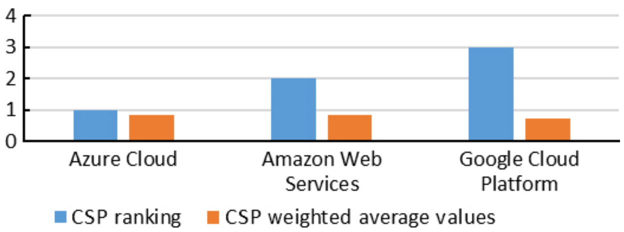

Fig. 5 Experiment 2 results.

Table 15 Weighted average values and ranking in Experiment 3.

Ranking	Sorted value	Cloud service provider
1	0.8875	Google Cloud Platform
2	0.820 83	Amazon Web Services
3	0.791 66	Azure Cloud

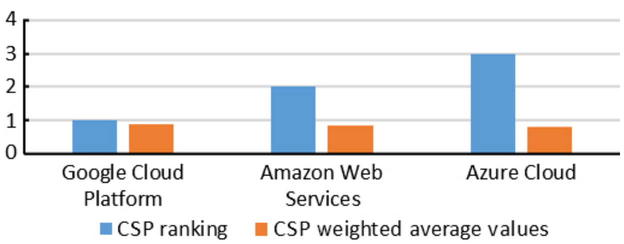

Fig. 6 Experiment 3 results.

the most suitable CSP based on the software requirement specification. However, evaluation metrics considered in this work concerning software requirement specifications in relation to the top three CSPs identified. Thus, future works must propose general evaluation models

Table 16 Weighted average values and ranking in Experiment 4.

Ranking	Sorted value	Cloud service provider
1	0.625	Google Cloud Platform
2	0.525	Azure Cloud
3	0.425	Amazon Web Services

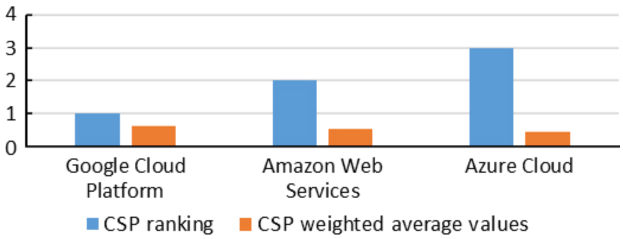

Fig. 7 Experiment 4 results.

addressing all CSPs, which must be refined with the use of additional metrics.

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