

# Multi-criteria Decision-making in Cloud Service Selection and Adoption

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**Abstract**—Cloud computing (CC) offers its unique scalable and all time available services to the user. As service provision is an important part of the Cloud computing concept, the proper choice of the needed service according to the users' needs is of most relevance. This research provides a review of Cloud service selection approach of multi-criteria decision analysis (MCDA). MCDA enables the user to choose from several available choices based on the chosen criteria. In this paper, the criteria and subcriteria for choosing Cloud services in accordance with Cloud computing service model have been analysed.

**Keywords**- Cloud computing, decision-making, multi-criteria decision analysis, choice of criteria

## I. INTRODUCTION

The emergence of Cloud services is one of the breakthrough points in the history of computing. Cloud services are offered in three models of computing to the end user, and those are Software as a Service (SaaS), Platform as a Service (PaaS), and Infrastructure as a Service (IaaS) [1].

The proposed Cloud services and their applicability and adoption for the customer are described in Chapter 2. When Cloud computing customers are making decision about selecting the most appropriate service; at first, they consider the nature of their individual needs and ask themselves many questions about the Cloud adoption issue. Those questions become decision-making criteria and customers' needs become a unique use-case scenario of Cloud service demand. Using Multi-criteria Decision Methods (MCDM), the posed criteria can be evaluated and the selection of a proper Cloud service can be made.

This research aims to gather knowledge about the selection and adoption of Cloud services using MCDM methods for all three types of Cloud-services individually.

Chapter 3 gathers most popular existing MCDM methods for different user's use-case scenarios of selecting the proper Cloud service. As customer must select the best service according to their needs out of the abundance of possibilities, complex dependencies and heterogeneous sets of criteria must be well considered [2].

The provided overview of the gathered research knowledge is set in a comparative table (Chapter 3) and discussed in Chapter 4, offering conclusive facts regarding the selection process of the most appropriate service for Cloud customer.

## II. APPLICABILITY AND ADOPTION OF CLOUD COMPUTING SERVICES

The following text of this Chapter provides the description of three main Cloud computing models which are the subject of research in defining the key criteria as an integral component of multi-criteria analysis.

### A. IaaS

Infrastructure as a Service (IaaS) refers to the provision of raw machines (servers, storage, networking and other devices) on which the service consumers deploy their own software (usually as virtual machine images). IaaS providers host users' applications and handle tasks including system maintenance, backup and resiliency planning. IaaS platforms offer highly scalable resources that can be adjusted on demand. This makes IaaS well-suited for workloads that are temporary, experimental or change unexpectedly. Other characteristics of IaaS environments include the automation of administrative tasks, dynamic scaling, desktop virtualization and policy-based services.

IaaS customers pay on per-use basis, typically by the hour, week or month. Some providers also charge customers based on the amount of virtual machine space they use. This pay-as-you-go model eliminates the capital expense of deploying in-house hardware and software. Once the new software is tested and refined, it can be removed from the IaaS environment for a more traditional in-house deployment or to save money and free the resources for other, new projects. Leading IaaS providers include Amazon, Dimension Data, Windows Azure, Google Compute Engine, Rackspace Open Cloud, and IBM SmartCloud Enterprise, etc. [3]- [4]- [5].

### B. PaaS

Platform as a Service (PaaS) is a provision service of development platform and environment providing services and storage, hosted in the Cloud. Most PaaS platforms are geared toward software development and offer developers several advantages. For example, PaaS allows developers to frequently change or upgrade operating system features. Also, PaaS is found very helpful for collaboration of development teams on projects.

Users typically access PaaS through a Web browser. PaaS providers charge for the access the users have made on a per-use basis. Some PaaS providers charge a flat monthly fee to

access the platform and the apps hosted within it. When making decision about PaaS service, it is important to evaluate service uptime and support offered by the considered PaaS provider.

Salesforce.com's Force.com is a well-known PaaS vendor that provides an enterprise customer relationship management (CRM) platform. Other PaaS platforms for software development and management are Apper IQ, Mendix, Amazon Web Services (AWS) Elastic Beanstalk, Google App Engine, Red Hat, Heroku, etc. [3]- [4]- [5].

### C. SaaS

Software as a Service (SaaS) is a software distribution model in which third-party provider hosts applications and makes them available to customers over the Internet. SaaS is used in a number of common business areas, including customer relationship management (CRM), document management, accounting, human resource (HR) management, service desk management, content management and collaboration.

SaaS customers have a lot of choice among providers. When making the selection, security and all-time-availability of service are most often the demand criteria. Except for the mentioned and according to their specific needs, customers usually pose a wide set of criteria as there are thousands of SaaS vendors on the global Cloud service market, such as Salesforce.com, Oracle, Google and SAP.com, Apprenda, Cloudswitch, Marketo, Pardot, etc. to choose from [3]- [4]- [5].

## III. REVIEW OF CLOUD SERVICE SELECTION AND ADOPTION

Within this chapter, a review of Cloud service selection and adoption is given through three substantial Cloud services – IaaS, PaaS and SaaS, separated in individual sub-chapters.

### A. IaaS

As most IaaS Cloud computing service packages cover the storage, networking, servers, and virtualization components, and the IaaS customers are usually responsible for installing and maintaining the operating system, databases, security components, and applications, decision-making is of extreme importance. For the IaaS, there is a great number of methods, as all MCDM methods can be used. It is up to the user needs and use-case scenario which of the MCDM methods will perform better.

The research [6] states that Analytic Hierarchy Process (AHP) is the most efficient MCDM method for managing information security in Cloud computing as well as for task scheduling and resource allocation.

The main limitation of multi-criteria optimization techniques such as genetic algorithms, is that they cannot handle mixed qualitative and quantitative criteria. Therefore, research [1] applies a finite set of alternative purposes and uses AHP to resolve mixed quantitative and qualitative criteria. The research proposes a hybrid multi-goal optimization heuristic method, i.e. the use of optimization techniques such as genetic algorithm (GA) together with AHP to easily evaluate alternatives and find an optimal solution according to the AHP-based evaluation.

Research [5] proposes a Cloud service selection model based on the Analytical Network Process (ANP). According to the proposed model, the criteria and subcriteria (subfactors) for Cloud service selection are identified and evaluated by weights. ANP is one of techniques suggested to solve complex decision-making problems and therefore it is relevant for identification of the best choice of IaaS service. For the organization of choice selection model, paper [5] uses three criteria (support perspective, provider perspective and service perspective), and eight subcriteria (service brand, service price, availability, performance, scalability, security, service level agreement and service support). Based on the chosen criteria and the ANP method, the research makes a selection out of six proposed IaaS alternatives (6).

Research [6] explores use-case scenario for different multi-criteria decision-making in Cloud computing. Also, the strengths and weaknesses are provided for every multi-criteria decision-making described. The analyzed methods are AHP, TOPSIS, VIKOR, ELECTRE and PROMETHEE. This research evaluates the methods of Cloud service selection and is relevant for selecting the most efficient method for the type of Cloud service of interest.

Research [7] describes decision-making of small and medium enterprises (SME) about the choice of Cloud services, as well as their valorization criteria. The research explores the use of AHP method for decision-making in the Cloud environment. The proposed AHP model has offered financial, marketing, management and environment criteria (4), and 14 subcriteria, such as often considered payment on demand, intensive and timely information, the performance of CRM application, information security and privacy, agility and adaptability, Cloud technology reliability, etc. The method has added values (weight) for every criterion and ranked subcriteria by order of importance.

Research [8] offered a concise practical approach to choosing a Cloud provider. The authors have explored AHP and PROMETHEE (Preference Ranking Organization METHod for Enrichment Evaluations) and the Goal programming techniques for assessing the weights of the selected criteria. The research has chosen 12 criteria; security protocols enabled, file sharing capabilities, maximum file size upload, free storage space, supported operational systems, ease of use, technical support, version control, service provider reputation, additional free storage space, mobile internet support and market share. Dropbox, SugarSync, Google Drive, Microsoft SkyDrive, Apple iCloud, Amazon, MegaCloud, JustCloud and Ubuntu One were evaluated according to the stated criteria. The choice of Cloud provider was finally obtained, and PROMETHEE has given SugarSync, GoogleDrive and Microsoft SkyDrive as top three providers, while AHP has given SugarSync, Dropbox and JustCloud as top three on the rank list.

Research [9] describes decision-making of a business migrating to the Cloud. The research does not propose any methodology of choice, but offers the identification of several criteria of vendor evaluation, and those are accountability, agility, assurance, costs, performance, security and privacy.

Research [10] has chosen two (2) methods – TOPSIS (Technique for Order of Preference by Similarity to Ideal Solution) and VIKOR (VIseKriterijumska Optimizacija I Kompromisno Resenje) for IaaS Cloud service selection. The authors proposed a new decision-making model made of these two, with one method as the main method and the other as an instance method. The developed decision-making evaluation model contains three criteria, i.e. values of RAM, Bandwidth and Storage. After a 30-day evaluation of TOPSIS and VIKOR with ten (10) Cloudsim toolkit simulated Clouds, VIKOR has outperformed TOPSIS, in terms of evaluated criteria of memory and time.

Paper [11] has presented a fuzzy multi-criteria group decision-making method for evaluating the performance and the choice of Cloud services. Based on the gathered literature, the most relevant criteria were chosen, and those are security, performance, accessibility, usability, scalability, and adaptability.

Paper [12] provides an overview of different MCDM methods and their evaluation. The seven MCDM methods are used (7), and those are Outranking Methods, TOPSIS, PROMETHEE, Multi-Attribute Value Theory (MAVT), Multi-Attribute Utility Theory (MAUT), Elimination Et Choice Translating Reality (ELECTRE) and AHP. The research had also provided comparative study of the given MCDM methods with their strengths and weaknesses.

Research [13] uses multi-criteria decision-making methods to rank the service providers based on their infrastructure parameters. A combination of analytic and fuzzy method is found more trustworthy in comparison with any analytic method alone. Ranking of Cloud Service Providers (CSPs) is based on the Key Performance Indicators called Service Measurement Index (SMI) which help the organizations measure the Cloud-related business services based on their specific business and technology requirements. The indicators considered in the trust estimation of CSPs are agility, financial, performance, security and privacy, and usability (5). For the comparison of services, four (4) infrastructure CSPs were considered: Gogrid, Rackspace, Amazon EC2 and Cloudflare (alternatives).

### B. PaaS

PaaS is often an IT business choice, as it can edit the operating system features and easily upgrade, and its major focus is on security, storage and database integration. PaaS services can be used from variety of international sources. PaaS Cloud solution serves as an application hosting, testing, deployment and development environment with reduction of total expenses involved.

Research [14] compares prominent PaaS Clouds: Microsoft Windows Azure (MWA), Google App Engine (GAE) and GroundOS (GOS) by several criteria of choice, and those are programming language and frameworks, databases, availability, security, services, customer care and price (7). The research has not proposed a method for the selection of PaaS provider.

Table 1 shows more significant studies that are associated with the application of multi-criteria decision-making in cloud service selection (related to cloud models).

TABLE I. STUDIES ASSOCIATED WITH THE APPLICATION OF THE MULTI-CRITERIA DECISION-MAKING IN CLOUD SERVICE SELECTION (RELATED TO CLOUD MODELS)

Studies	Year	Methods (MCDA)	Model of Cloud services	Number of criteria / subcriteria	Note
B. Do Chung and K.-K. Seo [5]	2015	ANP	IaaS	3 criteria and 8 subcriteria	Evaluation of 6 Cloud services
D. Rai and V. P. Kumar [10]	2016	TOPSIS and VIKOR	IaaS	3 criteria	Evaluation with 10 Cloudsim toolkit simulated Clouds
M. Supriya, K. Sangeeta, G.K. Patra [13]	2016	AHP, Fuzzy-AHP, TOPSIS and Fuzzy-TOPSIS	IaaS	5 criteria	Evaluation of 4 Cloud services: Gogrid, Rackspace, Amazon EC2 and Cloudflare
S. Lee and K.-K. Seo [21]	2013	AHP	IaaS	3 criteria and 8 subcriteria	-
T. Devi, R. Ganesan [14]	2015	-	PaaS	7 criteria	Evaluation of 3 PaaS Clouds: Microsoft Windows Azure (MWA), Google App Engine (GAE) and GroundOS (GOS)
J.J.H. Park, H-Y. Jeong [3]	2013	A new QoS-based MCDM system is proposed	SaaS	6 criteria and 25 subcriteria	Evaluation of 3 different types of SaaS ERP systems
P. Costa [15]	2013	MACBETH	SaaS	19 criteria	Evaluation of 2 Cloud services: Google Apps and Microsoft Office 365
M. Godse, S. Mulik [16]	2009	AHP	SaaS	5 criteria and 16 subcriteria	Evaluation of 3 leading SaaS products (as A, B, and C instead of using their real names)
N. Boussoualim and Y. Aklouf [18]	2014	AHP	SaaS	7 criteria and 25 subcriteria	Evaluation of 3 SaaS offers (A, B, and C)

O. Boutkhom, M. Hanine, T. Agouti and A. Tikniouine [20]	2016	Fuzzy AHP and PROMET HEE	SaaS, PaaS and IaaS	3 criterias and 10 subcriteria	Evaluation of 5 Cloud computing products
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Research [6] proposes different MCDM methods for different Cloud services. The authors emphasize the use of all MCDM methods for decision-making on all Cloud services, regardless of the model, but they suggest the use of TOPSIS for PaaS decision-making.

### C. SaaS

Decision-making problems in SaaS environment are of great importance. For example, SaaS vendor selection is one of the scenarios where multi-criteria decision-making is necessary. The method that is most commonly used to resolve SaaS-related decision-making problem is AHP, which is used for SaaS vendor selection, SaaS product selection, customer centered Cloud service selection and ranking of Cloud computing services [6].

The author of research paper [15] uses MACBETH (Measuring Attractiveness by a Categorical Based Evaluation Technique) method to simplify the decision-making process in organizations adopting Cloud services. The proposed solution model is based on 19 chosen criteria that facilitate decision-making among two SaaS Cloud services: Google Apps and Microsoft Office 365 (2). Some of those criteria are commonly used in MCDM, such as availability, data integrity, maintainability, interoperability, service response time (SRT), cost, confidentiality and data loss, reliability, compliance with standards, laws and regulations, service level agreements capacity (SLA), innovation, client support, risks, acquisition and transaction cost, adaptability, elasticity, etc. Also, some are more specific in nature, like service response time, service level agreement, acquisition and transaction cost, confidentiality and data loss. The proposed evaluation criteria are individually described with performance reference levels, as either good or neutral.

Paper [16] presents an approach of using the AHP technique for prioritizing Cloud service features and ranking (three Cloud services). Based on the experience and the opinion of experts, the research proposes the following criteria for the selection of SaaS, and those are functionality, architecture, usability, vendor reputation, and cost (5).

Research [3] proposes the use of QoS model to make a service selection. The model consists of six (6) criteria: functionality, reliability, usability, efficiency, maintainability and portability, and 25 subcriteria: suitability, accuracy, interoperability, compliance, sustainability, maturity, recoverability, fault tolerance, elasticity, security, learnability, easy to use, operability, scalability, adaptability, time behavior, resource behavior, throughput and efficiency, stability, analyzability, changeability, testability, updateability, service use cost and update cost. The proposed QoS model is in fact a multi-criteria decision-making (MCDM) model formed to find the best SaaS ERP (Enterprise Resource Planning) in the Cloud

computing environment and provide recommendations to customer in provided priority order.

Research [17] proposed a primitive cognitive network process (P-CNP) for SaaS evaluation and selection problem. Further research lies in planning to integrate the PROMETHEE and fuzzy technique into the P-CNP to form a new enhanced hybrid decision-making model.

Research [18] used 7 criteria and 25 subcriteria for the selection of SaaS Cloud service. The method used in research is AHP. Proposed criteria were CRM, collaboration, reputation, cost, usability, structure, configurability and personalization, and subcriteria included commonly mentioned safety, scalability and success control among the rest.

Research [19] used a Petri net multi-criteria decision-making (MCDM) framework to evaluate SaaS. The strategy, quality, performance, security and economic criteria were evaluated.

## IV. DISCUSSION & CONCLUSION

Based on the gathered, there are several multi-criteria decision methods that are used most for resolving the selection problems of Cloud environment. The methods that are found as the most efficient ones are AHP, ANP, Fuzzy-AHP, PROMETHEE, TOPSIS, Fuzzy-TOPSIS, VIKOR and ELECTRE. The often mentioned and used decision-making criteria are security, performance, accessibility, usability, scalability, and adaptability. Those are the criteria that most precisely correspond to the customer (i.e. user) needs when making the Cloud service selection. For every business decision of Cloud service selection, the costs seem to be highly evaluated, followed by privacy and security matters. It is also noticeable that when deciding about SaaS, the future customer imposes more criteria and subcriteria in number to decision-making (Table 1). Also, the majority of organizations adopting SaaS are interested in agility and innovation; those adopting PaaS are interested in scalability, and the companies that adopt IaaS Cloud service most often expect capital and operational expenditures and therefore high demand of agility.

The research has found that not every decision-making method is the best for every Service of Cloud computing environment. Depending on the nature of Cloud computing selection problem there are options that are found most efficient. For example, for SaaS AHP is recommended, for PaaS TOPSIS and for IaaS all the MCDM methods are found equally appropriate. With the use of several basic MCDM methods, more precise hybrid methods are being proposed. Hybrid, i.e. expanded and combined, methods strengthen the customer confidence in the method and facilitate the final decision.

Further research will include a more practical approach regarding Cloud service selection and adoption. The following research will provide the evaluation results of criteria that are found as relevant within this research, all with the use of AHP and PROMETHEE MCDM methods (using the appropriate program tools). The emphasis shall be on the ranking procedure of user requests (criteria and subcriteria) regarding the required Cloud services. Accordingly, appending the priorities and preferences to certain criteria and alternatives

(Cloud services and/or product) will be of the utmost importance.

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