Ranking CloudService Providers using SWARA and VIKOR (A case of Irancell Company)

Zohreh Akbarizadeh
Master of IT Management / Islamic Azad University E-Campus
Tehran, Iran

Mahdi Faghihi
Assistant professor of Iran Parliament research center
Tehran, Iran

Abstract
Cloud computing is a recent computing paradigm that represents a fundamental change of information communication technology (ICT) services and Cloud services continue to grow rapidly with increasing functionality and more users. As a result of this growth, it is a critical issue to select a suitable Cloud service which meets all the business strategies and the objectives of firms. This paper proposes a hybrid multi-criteria decision-making model for a Cloud service selection problem using SWARA, and VIKOR techniques. For this aim, the list of important decision making factors was selected based on literature review and the decision makers' opinions. Then, SWARA was utilized to calculate the weights of selected criteria and sub criteria and VIKOR was applied to rank the Cloud service providers. Our findings can be utilized as bases to apply systematic decision-making processes for the best Cloud service selection and for giving direction to IT office managers with respect to performance assessment and techniques to enhance companies' performance and capability.

Keywords:
CloudService; ranking providers; Multi-Criteria Decision-Making; SWARA; VIKOR

1. Introduction
In recent years, Cloud computing has emerged as one of the most popular network computing paradigms (Gonçalves Junior et al, 2015) as it provides affordable access to reliable high-performance hardware and software resources (Jula et al, 2014) and it also provides a robust and dynamic computing environment for end users that allow users' access and processing of their files from virtually anywhere, provided that an internet connection is available (Papathanasiou et al, 2015). Large institution managers and stakeholders of information technology companies have been encouraged to migrate to Cloud computing regarding the maintenance cost avoidance and security concerns (Jula et al, 2014) thus they can concentrate more on their core business development (Gonçalves Junior et al, 2015). In other words, using Cloud services has many benefits such as increased business agility, IT control, cost efficiency, and productivity, as well as a reduction in the number of management resources that are required. Regarding the note that data are scattered in different data centers and applications are in remote servers in today's technology era, the Cloud technology brings the scattered data and the remote applications to user laptop irrespective of time and location (Zhou et al, 2011).
Regarding the development of Cloud computing technology, and as more organizations consider migrating or developing systems in the Cloud, a variety of Cloud services are also emerging. Correspondingly, evaluating the Cloud services in order to select the most suitable Cloud service and the highest quality Cloud offerings has become a key issue for users as it is difficult for users to compare the Cloud services offered by the different providers and it is uneasy to make decision about the services meeting their requirements. Consequently, the Cloud users face a challenge to select an appropriate provider taking into account their specific requirements.
Multi Criteria Decision Making (MCDM) methodologies are well–suited to the complexity of decision problems and significantly improve the robustness of analysis and business decisions in general (Balzentis et al. 2012). For this reason, SWARA and VIKOR are used to analyze the gathered data based on the purpose of the study. First SWARA will be used to determine the weight of main criteria and sub criteria, and then VIKOR will be applied for ranking the Cloud service providers of Irancell Company.
In the next section, the relevant literature is presented and the theoretical framework adopted in this study is discussed. This is followed by a description of the study's overall research design and methodological issues. The study's main findings are presented in finding analysis section and, finally, conclusions and remarks are then given. The framework of the research is illustrated in figure 1.

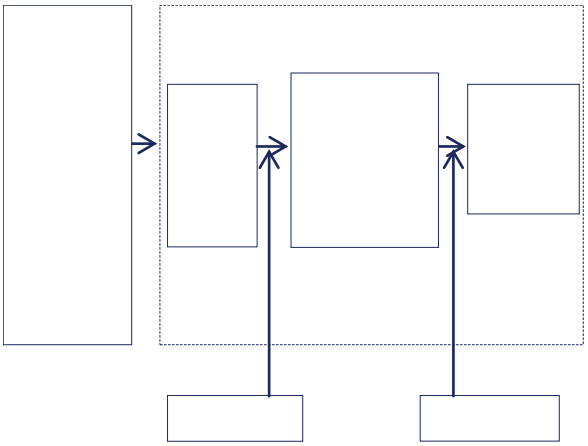

Fig. 1: The research framework from Garg et al. (2013)

2.Literature Review

There are different definitions for Cloud computing in the literature, among which the most accepted one is the Cloud definition provided by the National Institute of Standards and Technology (NIST) (Peter Mell, 2011).The NIST Cloud computing definition: ‘‘Cloud computing is a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction. This Cloud model is composed of five essential characteristics, three service models, and four deployment models’’.

The Cloud Service Measurement Index Consortium (CSMIC) has introduced criteria that are combined in the form of the Service Measurement Index (SMI) to evaluate Cloud services that can be used by potential users to compare different Cloud service providers based on their requirements and priorities (Garg et al, 2013). In the following, some of the latest researches in the field of Cloud services is presented.

Liu et al. (2016) proposed an attribute ranking method based on the rough set theory to provide a guide choosing the appropriate Cloud services for Cloud users. Their proposed method has the ability to explore the significant factors affecting the adoption of Cloud services for users and help the Cloud service providers to specifically improve their quality of services to win more customers. Their experimental results showed that their approach is effective in services matching.

Gonçalves Junior et al (2015) presented an approach that considers non-functional requirements (NFRs) as key drivers for analyzing, based on a multi-criteria method, the best architectural options for applications that are deployed and configured in the Cloud. Results from a real application (WordPress) deployed on a popular Cloud provider (Amazon) showed that depending on the quality parameters and characteristics of the application including Response Time, CPU Utilization, Memory Utilization, Scalability and Cost, the results for the most appropriate architecture can vary a lot based on the NFRs selected and also the Cloud services chosen for the architectural alternatives.

Papathanasiou et al (2015) used two multi-criteria methodologies namely PROMETHEE and AHP to select appropriate Cloud computing services providers. The criteria used in this study included 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 under conditions, Mobile Internet support (iOS, Blackberry, Android, etc.) and Market share. The service providers were companies such as Dropbox, GoogleDrive, Microsoft SkyDrive, SugarSync, Apple iCloud, MegaCloud, Amazon, Just Cloud, Mozy, Box.net.The results of both methodologies yielded SugarSync as best provider.

Lee and Seo (2015) applied BSC and FAHP as the hybrid multi-criteria decision-making technique to select the best Cloud service. The indicators used in each BSC perspectives were as follows: Financial (ROI or NPV, Service Introduction Cost, Maintenance Cost); Customer; (Internal Satisfaction, Availability, Accuracy, Security); Internal business process (Average capacity and stability, Internal process simplification, Performance); Learning and growth (Innovation on legacy systems, Scalability, Agility, Compliance).

Jiang et al (2015) developed an evaluation index system for the decision-making of selecting

Cloud service (EIS-DMSCS) and proposed an information-entropy-based decision-making

method for the selection of Cloud computing service.Resource Condition (State of IaaS, State of PaaS, State of SaaS), Service Utility (Usability, Reliability, Response Time), Security (Privacy Security, Technology Security, Operation Management Security), Service-Level Agreement (Sigma completeness, Transparency and Creditability, Punishment Mechanism), Economic Factors (Service Price, Payment Ability) were the criteria and sub-criteria used in this research and the best provider was selected based on Information Entropy.

Jula et al (2014) conducted a systematic literature review on the Cloud computing service composition. This investigation demonstrates that all Cloud computing service composition innovations and improvements can be categorized into the following five groups: classic and graph-based algorithms, combinatorial algorithms, machine-based methods, structures and frameworks and the most widely applied category is the classic and graph-

based algorithms group, and the least used categories are machine-based methods and structures. Considering the parameters of quality of service, cost, response time, availability, reliability and reputation were recognized as significant QoS parameters.

Garg et al. (2013) proposed a framework and a mechanism that measure the quality and prioritize Cloud services. In their framework, the authors presented a rank Cloud services mechanism using AHP (Analytic Hierarchy Process) for solving problems related to MCMD (Multiple-Criteria Decision-Making). Accountability, Agility, Assurance of Service, Cost, Performance, Security and Privacy, and Usability were the quality criteria used in this work.

After reviewing the literature related to Cloud service quality parameters and Cloud service provider selection indicators, the present study adopted the Quality of Service (QoS) presented by Garg et al (2013).

The Service Measurement Index (SMI) framework provides a holistic view of QoS required by the customers to select a Cloud service provider based on: Accountability, Agility, Assurance of Service, Cost, Performance, Security and Privacy, and Usability (Garg et al, 2013). In the following, a brief explanation of these criteria and their related sub-criteria is presented.

Table 1: The research criteria and sub-criteria adopted from Garg et al (2013)

Criteria	Sub-criteria
Accountability	Auditability
	Compliance
	Data ownership
	Provider ethicality
Agility	Flexibility
	Elasticity (how much a Cloud service can be scaled during peak times)
	Adaptability (the ability of the service provider to adjust changes in services based on customers' requests)
Cost	Cost effectiveness
Assurance	Service stability (the variability in the performance of a service)
	Service resiliency
	Service reliability (how a service operates without failure during a given time and condition)
Performance	Service response time
	Service accuracy (the degree of proximity to the user's actual values when using a service compared to the expected values)
	Scalability (determine whether a system can handle a large number of application requests simultaneously)
	Suitability (the degree to which a customer's requirements are met by a Cloud provider)
Security and Privacy	Protecting confidentiality
	Protecting privacy
	Data integrity and availability (the percentage of time a customer can access the service)
Usability	Accessibility
	Learnability
	Operability (the ability of a service to interact with other services offered either by the same provider or other providers)
	Install ability

After identifying the parameters of service quality, this work applied a multi-criteria method that considers the service quality criteria for analyzing the best options among the Cloud service providers. For this aim, the importance of each criteria and sub-criteria is calculated and the final rank of each providers is computed using MCDM techniques that are elaborated in methodology section.

3.Methodology

In order to perform this research study, a questionnaire survey was conducted. The population of this study includes executive managers and experts with over 10 years of experience and with at least a master's degree in Irancell Company that is one of the biggest mobile phone network operators in Iran. In this research SWARA was used to evaluate and calculate the relative importance of each criterion and VIKOR was applied to rank the alternatives. In order to gather data, a questionnaire was used to obtain the weights of the criteria and sub-criteria based on SWARA method. The SWARA questionnaire was distributed among experts and gathered in two phases according to SWARA methodology. After obtaining the weightsaccording SWARA method, the next questionnaire was de-

signed based on VIKOR technique and was distributed and collected among the experts to calculate the ranking of the alternatives. The gathered data was analyzed using SWARA and VIKOR methodology.The background information of the experts is presented in table 2.

Table 2: Background information of experts.

Category	Classification	No.
Working in background	IT Manager Data center Manger Cloud Computing expert Virtualization expert Marketing expert	1 1 3 2 1
Education Level	Bachelor Master Ph.D.	0 5 2
Gender	Male Female	7 1

In summary, the research is conducted as follows:
1. Identifying the influencing criteria of Cloud services
2. Designing the first questionnaire of SWARA method to determine the priority of the identified criteria and sub-criteria in the previous step to be completed by the experts
3. Designing the second questionnaire of SWARA method to determine the weights and importance of each criteria and sub-criteria using SWARA method
4. Calculating the weights of each criteria and sub-criteria based on SWARA method
5. Designing the third questionnaire to gather the necessary data to rank Cloud service providers based on VIKOR technique.

Many MCDM models studied in the previous works for various applications such as AHP (analytic hierarchy process), DEA (data envelopment analysis), TOPSIS (technique for order preference by similarity to ideal solution), ELECTRE II (Elimination and Et Choice Translating Reality) and so on. However, over the last decade, scientists and researchers have developed a set of new MCDM methods. The new Step-wise Weight Assessment Ratio Analysis (SWARA) technique was proposed by (Kersuliene et al., 2010). Although it is a newly proposed method, it was used to solve many problems such as a rational dispute resolution (Kersuliene et al., 2010), the design of products (Hashemkhani Zolfani et al., 2013), a machine tool selection (Aghdaie et al., 2013),selection of a packaging design (Stanujkic et al, 2015) and so on. In the present work, SWARA method was used to calculate the weights of criteria and sub-criteria and VIKOR technique was applied to rank the Cloud service providers. In the following, the two methods are explained.

3.1.SWARA Method

The process of determining the relative weights of criteria using SWARA method was conducted using the following steps as stated in (Kersuliene et al., 2010):
Step 1. Sort the criteria in descending order based on their expected significances.
Step2.Starting from the second criterion, the relative importance of criterion j in relation to the previous (j-1) criterion must be expressed by the respondent, for each particular criterion. According to Kersuliene et al. (2010), this ratio is called the Comparative importance of average value, sj.
Step 3. The coefficient kj is determined as follows

$$k_j = \begin{cases} 1 & j = 1 \\ s_j + 1 & j > 1 \end{cases} \quad (1)$$

Step 4. The recalculated weight qj is determined as follows:

$$q_j = \begin{cases} 1 & j = 1 \\ \dfrac{k_{j-1}}{k_j} & j > 1 \end{cases} \quad (2)$$

Step 5. The relative weights of the evaluation criteria are determined as follows:

$$w_j = \frac{q_j}{\sum_{k=1}^{n} q_j} \quad (3)$$

where wj denotes the relative weight of criterion j.

3.2.VIKOR

The VIKOR method was introduced for multi-criteria optimization problem. This method focuses on ranking and selecting from a set of alternatives, and determines compromise solution for a problem with conflicting criteria, which can help the decision makers to get a final solution. Here, the compromise solution is a feasible solution which is the closest to the ideal, and a compromise means an agreement established by mutual concessions

(Opricovic & Tzeng, 2007). It introduces the multi-criteria ranking index on the base of the particular measure of ‘‘closeness” to the ‘‘ideal” solution (Opricovic, 1998). The compromise ranking algorithm of the VIKOR method has the following steps:

Step 1.Determine the best f_j^* and the worst f_j^- values of all criterion functions . If the jth function $j = 1,2,...,n$ represents a benefit, then:

$$f_j^* = \max_i f_j \quad (4)$$

$$f_j^- = \max_i f_j \quad (5)$$

Step 2. Compute the values S_i and R_i ; $i = 1,2,...,m$, by these relations:

$$S_i = \sum_{j=1}^{n} w_j (f_j^* - f_{ij}) / (f_j^* - f_j^-) \quad (6)$$

$$R_i = \max_j w_j (f_j^* - f_j) / (f_j^* - f_j^-) \quad (7)$$

where w_j are the weights of criteria, expressing their relative importance.

Step 3. Compute the values Q_i : $i = 1,2,...,m$, by the following relation:

$$Q_i = v(S_i - S^*)/(S^- - S^*) + (1-v)(R_i - R^*)/(R^- - R^*) \quad (8)$$

$$S^* = \min_i S_i, S^- = \max_i S_i \quad (9)$$

$$R^* = \min_i R_i, R^- = \max_i R_i \quad (10)$$

v is introduced as weight of the strategy of ‘‘the majority of criteria” (or ‘‘the maximum group utility”), here suppose that $v = 0.5$.

Step 4. Rank the alternatives, sorting by the values S , R and Q in decreasing order.

4. Data Analysis

4.1. Calculating the relative importance of each criterion using SWARA

After gathering the questionnaires, criteria weights were calculated applying SWARA method and based on experts’ evaluations.Final results of SWARA method in weight assessment criteria are presented in the following tables.

Table 3: Final results of SWARA method in weight assessment criteria

Criterion	Comparative importance of average value sj	Coefficient kj = sj + 1	Recalculated weight Wj=K_(j-1)/Kj	Weight q_j=w_j/(∑w_j)
Usability	-	1	1	0.207
Security and Privacy	18.5%	1.185	0.843	0.174
Cost	16.8%	1.16	0.722	0.149
Performance	11.2%	1.112	0.649	0.134
Assurance	10.6%	1.106	0.587	0.121
Agility	10%	1.10	0.534	0.11
Accountability	9.3%	1.09	0.488	0.101

Table 4: Final results of SWARA method in weighting criteria of accountability

Criterion	Comparative importance of average value sj	Coefficient kj = sj + 1	Recalculated weight Wj=K_(j-1)/Kj	Weight q_j=w_j/(∑w_j)	Final weights
Data ownership	-	1	1	0.325	0.032
Provider ethicality	15%	1.15	0.869	0.283	0.028
Compliance	11%	1.11	0.783	0.255	0.025
Auditability	8.7%	1.87	0.418	0.136	0.013

Table 5: Final results of SWARA method in weighting criteria of agility

Criterion	Comparative importance of average value sj	Coefficient kj = sj + 1	Recalculated weight Wj=K_(j-1)/Kj	Weight q_j=w_j/(∑w_j)	Final weights
Adaptability	-	1	1	0.395	0.043
Flexibility	21.2%	1.212	0.825	0.326	0.035
Elasticity	16.8%	1.168	0.706	0.279	0.030

Table 6: Final results of SWARA method in weighting criteria of assurance

Criterion	Comparative importance of average value sj	Coefficient kj = sj + 1	Recalculated weight Wj=K_(j-1)/Kj	Weight q_j=w_j/(∑w_j)	Final weights
Service reliability	-	1	1	0.399	0.048
Service resiliency	23.12%	1.231	0.812	0.324	0.039
Service stability	17.5%	1.175	0.691	0.276	0.033

Table 7: Final results of SWARA method in weighting criteria of performance

Criterion	Comparative importance of average value sj	Coefficient kj = sj + 1	Recalculated weight Wj=K_(j-1)/Kj	Weight q_j=w_j/(∑w_j)	Final weights
Service accuracy	-	1	1	0.334	0.044
Service response time	25.62%	1.256	0.796	0.266	0.035
Suitability	21.87%	1.218	0.653	0.218	0.029
Scalability	19.37%	1.193	0.547	0.182	0.024

Table 8: Final results of SWARA method in weighting criteria of performance

Criterion	Comparative importance of average value sj	Coefficient kj = sj + 1	Recalculated weight Wj=K_(j-1)/Kj	Weight q_j=w_j/(∑w_j)	Final weights
protecting privacy	-	1	1	0.427	0.074
protecting confidentiality	32.5%	1.325	0.754	0.322	0.056
data integrity and availability	29.37%	1.293	0.583	0.249	0.043

Table 9: Final results of SWARA method in weighting criteria of usability

Criterion	Comparative importance of average value sj	Coefficient kj = sj + 1	Recalculated weight Wj=K_(j-1)/Kj	Weight q_j=w_j/(∑w_j)	Final weights
Accessibility	-	1	1	0.302	0.062
Learnability	15.62%	1.156	0.865	0.261	0.054
Installability	13.75%	1.137	0.76	0.229	0.047
Operatibility	11.25%	1.112	0.684	0.206	0.042

4.2. Ranking the pricing strategy using VIKOR techniques

As it is explained in VIKOR steps, the decision making matrix are normalized and the best and the worst values of all criterion are determines which are shown in the following tables.

Table 10: The normalized decision making matrix

U4	0.184	0.376	0.86	0.291
U3	0.271	0.453	0.546	0.639
U2	0.255	0.633	0.373	0.635
U1	0.112	0.342	0.801	0.46
SP3	0.45	0.672	0.56	0.112
SP2	0.198	0.376	0.864	0.282
SP1	0.27	0.453	0.553	0.647
P4	0.309	0.801	0.306	0.409
P3	0.31	0.699	0.311	0.554
P2	0.15	0.921	0.156	0.304
P1	0.281	0.712	0.27	0.569
As3	0.323	0.76	0.11	0.54
As2	0.252	0.63	0.378	0.63
As1	0.115	0.346	0.808	0.462
C1	0.453	0.679	0.566	0.113
Ag3	0.191	0.381	0.858	0.286
Ag2	0.275	0.458	0.55	0.642
Ag1	0.303	0.808	0.303	0.404
Ac4	0.314	0.707	0.314	0.55
Ac3	0.154	0.926	0.154	0.309
Ac2	0.286	0.714	0.286	0.571
Ac1	0.327	0.764	0.109	0.546
	Pars	Shatel	Arya	Tebyan

Table 11: f_i^* & f_i^-

0.036	0.008	0.028
0.03	0.013	0.017
0.034	0.014	0.02
0.05	0.007	0.043
0.029	0.005	0.024
0.048	0.011	0.037
0.047	0.02	0.027
0.019	0.007	0.012
0.021	0.009	0.012
0.032	0.005	0.027
0.031	0.013	0.018
0.025	0.004	0.021
0.025	0.01	0.015
0.039	0.006	0.033
0.101	0.017	0.084
0.026	0.006	0.02
0.022	0.01	0.012
0.035	0.013	0.022
0.018	0.008	0.01
0.023	0.004	0.019
0.02	0.008	0.012
0.244	0.035	0.209
F+	F-	F+-F-

Table 12: The Sj

Ac1	0.139	0	0.209	0.069
Ac2	0.012	0	0.012	0.004
Ac3	0.019	0	0.019	0.015
Ac4	0.01	0	0.01	0.004
Ag1	0.022	0	0.022	0.018
Ag2	0.012	0.006	0.003	0
Ag3	0.02	0.015	0	0.017
C1	0.034	0	0.017	0.084
As1	0.033	0.022	0	0.017
As2	0.015	0	0.01	0
As3	0.014	0	0.021	0.007
P1	0.018	0	0.018	0.006
P2	0.027	0	0.027	0.021
P3	0.012	0	0.012	0.005
P4	0.012	0	0.012	0.009
SP1	0.027	0.013	0.006	0
SP2	0.037	0.027	0	0.032
Sp3	0.01	0	0.005	0.024
U1	0.043	0.029	0	0.021
U2	0.02	0	0.014	0
U3	0.017	0.008	0.004	0
U4	0.028	0.02	0	0.024
Sj	0.582	0.139	0.421	0.378

S1: 0.582 S2: 0.139 S3:0.421 S4: 0.378

In accordance with Formula 4,5,6, and 7 the amounts of R were calculated.

R1: 0.139 R2: 0.029 R3: 0.209 R4: 0.084

In accordance with Formula 8,9 and 10 the amounts of Q were calculated

S+: 0.139 S-: 0.582

R+: 0.029 R-: 0.209

Q1: 0.194 Q2: 1.000 Q3: 0.181 Q4: 0.577

Q3> Q1 > Q4 > Q2

Based on the results, the final ranking of the Cloud service providers is as follows;

1. Arya Hamrah Samaneh Company
2. Pars Pak Company
3. Tebyan Company
4. Shatel Company

According the obtained results, Arya Hamrah Samaneh Company achieved the first rank and Pars Pak Company and Tebyan Company placed as the second and third companies, respectively.

5. Conclusion

The adoption and deployment of Cloud services have been greatly accelerated in recent years. In this respect, determining the important quality of service parameters and selecting appropriate services from a service pool have become a critical issue for Cloud service users regarding the rapid changes in the properties of the services and network. Therefore, this paper attempted to address this challenge by applying MCDM techniques to evaluate and rank Cloud service providers based on their ability to meet the users' requirements and to assure the service users' satisfaction. In this regard, SWARA method was used to calculate the relative importance of the identified influencing criteria and sub-criteria in QoS assessment of Cloud service providers and VIKOR technique was applied to calculate the ranking of the four Cloud service providers in Irancell Company in Iran.

The results of this study showed that usability, security and cost were the three influencing factors on the topic of Cloud services that were known important in the selection of companies offering cloud services. Taking into account of these priorities will reduce the failure rate in

goal achievement.

According the VIKOR results, Arya Hamrah Samaneh Company achieved the first rank and Pars Pak Company and Tebyan Company placed as the second and third companies, respectively.

Therefore, it can be concluded that simultaneous studying the criteria affecting the optimal decision in choosing the best Cloud service provider is critical in order to increase efficiency. The obtained weights and the priorities of each criterion can help the managers make the optimal decision and take the best actions and also plan their short and long term strategies.

The integrated proposed methodology can be used to make decisions more logical and reliable for decision makers. Ultimately, the authors recommend some topics to be done in future studies. The ranking of Cloud service providers can be done using TOPSIS, ELECTRE and other MCDM techniques and the researchers can conduct a study to identify other suitable quality indicators to improve decision making.

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