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COMPARISON STUDY BETEEN THE MULTI CRITERIA DECISION SUPPORT METHODS TO CHOOSE THE BEST APPROPRIATE CLOUD COMPUTING SERVICE PROVIDER

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Of

Electrical and Computer Engineering

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of Science

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2018

This is to certify that we have read this thesis and that in our opinion it is fully adequate, in scope and quality, as a thesis for the degree of Master of Electrical and Computer Engineering

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I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

Mabruka Khlifa Ali Karkeb

DEDICATION

Dedication for to my brother (Abd Alslam) May Allah have mercy on him who has always been with me through the hard times in his life also these moments when I get a master's was his dream. As well as dedicate this Thesis to Libya, It is my strong pillar for me. Also I dedicate this work to the parents (Khlifa , Hassna) who have encouraged me all the way and whose encouragement has made sure that I give it all it takes to finish that which I have started. To my sisters (Sabah ,Lila) , my brothers (Hassn ,Youssf , Ahamd, Abo Algasm) and whole my family who have been affected in every way possible by this quest. ,All of them without whom this thesis would not have been completed so thank you. My love for you all can never be quantified. Allah bless you.

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إهداء

إلى الوالدين........ فلولاهما لما وُجِدتُ في هذه الحياة، ومنهما تعلَّمت الصمود، مهما كانت الصعوبات.

إهداء

إلى روح أخى العـــزيز ، اقول لها كم تمنيت ان تكون معى بهذه اللحظـــات .

إهداء

إلى اخوتى و اخواتى الذين شاركوني بكل لحظات حياتى و وجودهم كان دعم كبير لي .

إهداء

إلى أساتذتي الكرام........، فمنهم استقيتُ الحروف ، وتعلَّمت كيف أنطق الكلمات ، وأصوغ العبارات ، وأحتكم إلى القواعد في مجال.....

إهداء

إلي ليبيا بـــلادي ، فهي كانت الدعم المادي و المعنوي لى و لكل الطلبة الليبيين طيلة مراحل حياتنا العلميـــة .

إهداء

إلى الزملاء والزميلات ، الذين لم يدَّخروا جهدًا في مدِّي بالمعلومات و البيانات.

أهدي إليكم جميعا أطروحـــــة الماجستير
داعيًة المولى سبحانه و تعالى أن تُكلَّل بالنجاح و القبول

ÖZET

En Iyi Uygun Bulut Bilişim Hizmeti Sağlayıcısı Seçmek Için Çok Kriterli Karar Destek Yöntemleri Arasında Karşılaştırma Çalışması

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Bulut Bilişim, depolama, işlemciler, bellek, vb. Kaynakların tüketiciden tamamen soyutlandığı özel bir dağıtık hesaplama şeklidir. Bilgisayarı bir hizmet olarak sunan Bulut Hizmet Sağlayıcılarının (CSP) sayısı kısa süre önce artmıştır ve birçok müşterinin, işlem yapmak için bilinmeyen hizmet sağlayıcılarla etkileşimde bulunması gerekir. Bu açık ve gizli ortamlarda güven, tüketici güvenini artırmaya yardımcı olur ve onlar için güvenilir bir ortam sağlar [8]. Güvene dayalı bir sıralama sistemi, onların ihtiyaçlarına göre hizmetler arasında seçim yapmalarına yardımcı olabilir. Bu araştırmada, hizmet sağlayıcıları altyapı parametrelerine göre derecelendirmek için çok kriterli karar verme yöntemleri (AHP, ANP, TOPSIS, ELECTRE, PROMETHEE ve VIKOR) kullanılmıştır. Daha sonra sonuçları sıralayan yöntemleri karşılaştırmak için bir karşılaştırma algoritması icat edildi. Bizim durumumuza ve kullanılan yöntemlere göre "Rackspace" sağlayıcısı diğerleri arasında en uygun olanıydı.

Anahtar kelimeler: Cloud Service Providers; multi criteria; decision making; AHP; ANP; TOPSIS; ELECTRE; PROMETHEE ;VIKOR

ABSTRACT

Comparison Study Between The Multi Criteria Decision Support Methods To Choose The Best Appropriate Cloud Computing Service Provider

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Cloud Computing, storage, processors, memory, etc. It is a special form of distributed computing, where resources are completely abstracted from the consumer. The number of Cloud Service Providers (CSPs) that offer the computer as a service has recently increased and many customers need to interact with unknown service providers to perform transactions. In such open and confidential environments, trust helps to improve consumer confidence and provides a reliable environment for them [8]. A trust-based ranking system can help them choose between services according to their needs. In this research, multi-criteria decision making methods (AHP, ANP, TOPSIS, ELECTRE, PROMETHEE and VIKOR) were used make rating for the providers according to their infrastructure parameters. Then a comparison algorithm invented to compare the methods ranking results. According to our case and used methods "Rackspace" provider was the most agreeable one between the others.

Keywords: Cloud Service Providers; multi criteria; decision making; ANP; AHP; TOPSIS; ELECTRE;VIKOR; PROMETHEE

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LIST OF ABBREVIATIONS

AHP..	Analytic Hierarchy Process
ANP..	Analytic Network Process
CIS..	Cloud Integrated Storage
CSP..	Cloud Service Provider
CSPs......................................	Cloud Service Providers
CSR..	Cloud Service Request
ELECTRE..............................	Elimination and Choice Translating Reality
IaaS..	Infrastructure as a Service
IT..	Information technology
MCDA....................................	Multiple Criteria Decision Analysis
MCDM....................................	Multiple Criteria Decision Making
PaaS......................................	Platform as a Service
PROMETHEE........................	Preference Ranking Organization Method for Enrichment Evaluations
QoS..	Quality of Service
SaaS......................................	Software as a Service
TOPSIS..................................	Technique for Order Preference by Similarity to Ideal Solution
VIKOR....................................	VlseKriterijumska Optimizacija I Kompromisno Resenje

1. INTRODUCTION

Cloud computing is a special form that is completely abstracted by the consumer of basic resources such as storage, processors and memory. It provides asked resources to the customers, where it enables the customer to access the requested service like the computing infrastructure or applications by subscription. Cloud Service Provider (CSP) provides many types of services, the basic types of them: Platform as a Service (PaaS), Software as a Service (SaaS) and Infrastructure as a Service (IaaS). Consumers benefit from them to install applications, store, and share, enable access to the content by the internet from any location. According to [2] these services help companies to reduce the capital and operational costs.

There are increasing in the Cloud Service Provider (CSP) s numbers in the market, which represent a problem to the customers to choose between them. Which in turn push the clients to deal with stranger service providers to utilize their tasks. In such a scenario, a rating system could help them to choose between the services as per their requirement. If not selecting appropriate service provider, a problems like services without desired quality and non fulfillment services may faced. Thus, the selection of a suitable service provider by reasoning and assessing the possible risks in carrying out transactions is necessary for providing a safe and trustworthy environment. So the customers need such a trustable evaluation system which help to minimize unexpected risks that can be faced by the unknown providers.

How are the service provider able to provide and finish the tasks through the availability, ability, security measures comparing to the other providers that what it the trust evaluation represent. And which in turn help the customers to feel confident with in such open markets filled with the unknown providers, and support their decisions in the selecting process to the provider’s which able to finish their tasks in perfect way. This also enables them to choose the most appropriate resources in the different infrastructure of cloud. Therefore service levels of different CSPs need to be evaluated in an objective way to ensure the previous measures of an application. These cloud services that exist at three levels of the cloud model, namely, (IaaS), (PaaS), and (SaaS) have to be evaluated using an efficient trust management model. [13]

Multiple Criteria Decision Analysis (MCDA) could be suggested as an applicable model, Jahan and Edwards defined it as following: [3]

MCDA is the abbreviation for Multiple Criteria Decision Analysis/Aiding, in some researches it's called: Multiple Criteria Decision Making (MCDM). is a branch from the operational research. Which in turn subfield from the mathematics. That helps to solve the optimization complex decision making problems by applying advanced analytical methods.

Operational research play an important role in solving problems in many fields. For that operational research engaged with the other science. MCDA benefits from the wide application area for the operational research and focuses on founding the best possible solution in the decision making problems which use multiple criteria.

In this research, MCDM methods:

1. Analytic Hierarchy Process (AHP),
2. Analytic Network Process (ANP),
3. Technique for Order Preference by Similarity to Ideal Solution (TOPSIS),
4. Elimination and Choice Translating Reality (ELECTRE),
5. Preference Ranking Organization Method for Enrichment Evaluations (PROMETHEE),
6. VlseKriterijumska Optimizacija I Kompromisno Resenje (VIKOR).

Which used to rank many service providers based on their infrastructure parameters, where these methods will help to sort the alternative providers according to their importance based on many criteria..

1.1 PROBLEM DEFINITION

There are limited literatures on Cloud Integrated Storage (CIS) evaluation and selection method, specifically those that can be applied for evaluating and selecting (CIS) based on their ability to meet Cloud Service Request (CSR) trust requirements. The primary issues which are not investigated by these methods are: [8]

7. The major concern of the cloud evaluation and selection methods lies on certain types of quantifiable criteria of Quality of Service (QoS), especially cost and performance
8. The majority of cloud evolution and selection methods rank CSPs alternatives based on matching (Concordance) between CIS features and CSR requirements, while rank CSP

based on mismatching (Discordance) between CIS features and CSR requirements has been ignored.

9. There is limitation in the exist methods to supports CSP to make a comparison between their CIS with other CSPs to identify unimproved limitations with their service.

The advantages that the CSP got when evaluate their CIS services comparing to other CSPs: [8]

10. Helping CSP to determine the unimproved gap within their CIS.
11. Helping CSP to figure the amount of improvements that must be made to their CIS to reach ideal trust level.
12. Giving a competitive advantage among the other CSPs.
13. Giving the CSP the ability to price their CIS services according to provided quality.
14. Giving the CSP the knowledge about the quality criteria which provided comparing to other CSPs.

Since there are many conflicting criteria to select and evaluate CIS based on trust. This study suppose a trust selection method based on MCDM. These methods able to solve MCDM problems when we have many confused and immeasurable criteria's. Such a method can help CSR to decide which CSP can meet their trust requirements before relaying applications, files, and data to cloud. In addition, it also attempts to provide guidance to CSPs to decide prioritize enhancement actions in order to fill the unimproved gap associated with their CIS to achieve ideal trust level.

1.2 RELATED WORK

Garg et. Al, suggested a trust estimation system using Analytical Hierarchical Process (AHP) as a tool which enable the decision makers to make a ranking based on qualitative and quantitative evaluations. The authors ignored other MCDM methods in their research. [5]

Pramod et Al, tried to analyze the performance of the general cloud, private clouds and hybrid clouds using the ANP method (as we see in figure 1). Researchers have discovered that the application of the ANP method in such cases is a resources consuming process for the formulation for double-based comparison matrices and acquisition of data. Approximately 184 matrices were created to complete the work. The comparison of criteria against double comparison is dependent on the users' knowledge and familiarity with the company.[6]

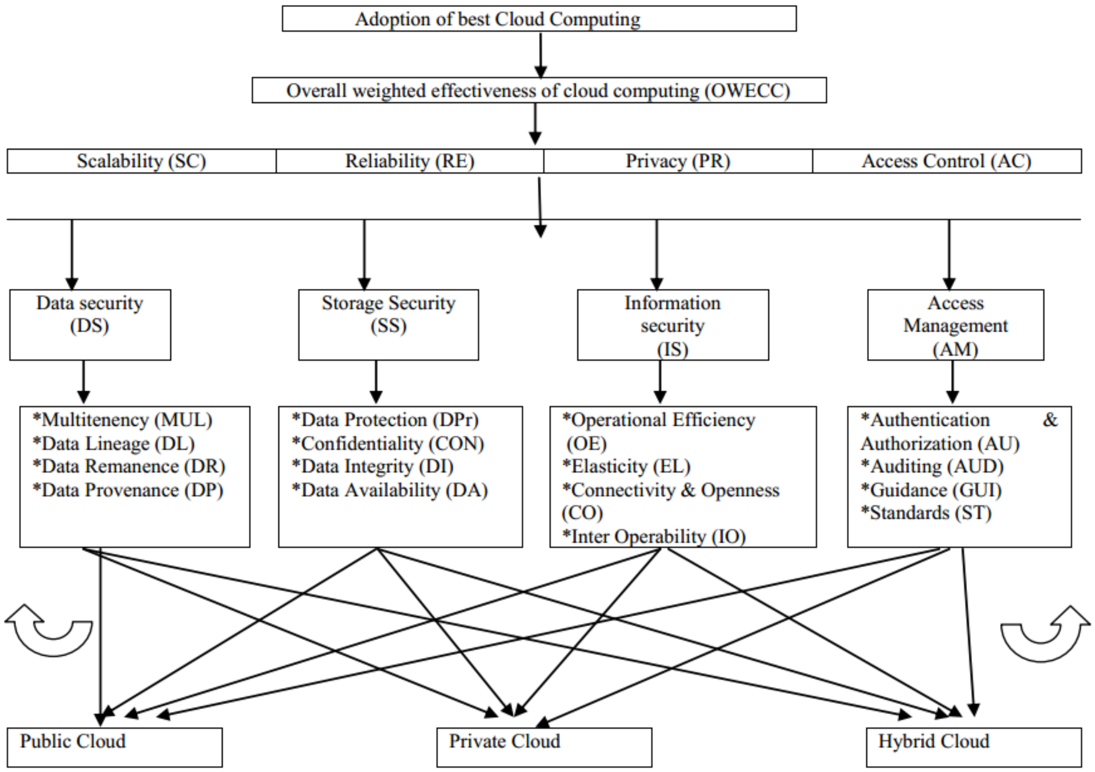


Figure 1-1 : Applying the ANP method [6]

Rehman et Al. discussed the application of ELECTRE, PROMETHEE, TOPSIS and AHP in thirteen CS and used five criteria in a case study, the result was as follows: we need more working to know the MCDM method which effectively used for IaaS selection with more dataset and criteria. However, TOPSIS, ELECTRE and PROMETHEE are more suitable for do that according to the research. TOPSIS is easiest when the number of services are large available due to simple calculation steps. When the number of alternatives is small, and criteria number high the pull-out methods are better [7]

The researchers used just some basic performance benchmarks, where they just used 5 criteria, and they didn’t use VIKOR method and ANP method. Figure 2 and 3, show the ranking for the CSPs by using ELECTRE, PROMETHEE and TOPSIS methods.

Alternatives	Summary Of Outranking Relationships			
	ELECTRE		PROMETHEE	
	R+	R-	R+	R-
1	10	0	10	2
2	1	8	2	8
3	0	9	0	12
4	7	2	8	3
5	7	1	12	0
6	5	1	6	6
7	4	3	5	7
8	3	4	2	9
9	3	5	3	8
10	1	8	1	11
11	3	3	7	5
12	0	3	8	3
13	3	0	1	1

Figure 1-2 : The result for ELECTRE, PROMETHEE methods [7]

Alternatives	A	B	C	D	E
1	0.33	1.00	**0.926***	0.648	0.009
2	0.09	0.87	1.663	0.682	0.032
3	0.00	1.00	1.995	0.655	**0.103***
4	**0.36***	0.76	1.162	**0.721***	0.014
5	0.00	1.00	1.357	0.691	0.020
7	0.10	0.86	1.356	0.638	0.021
8	0.01	0.96	1.480	0.636	0.038
9	0.04	0.92	1.481	0.630	0.029
10	0.00	1.00	1.653	0.644	0.067
11	0.22	0.71	1.166	0.653	0.015
12	0.18	**0.96***	0.983	0.623	0.010

Figure 1-3 : The result of TOPSIS method [7]

Alabool and Mahmood presented the fuzzy modified VIKOR to evaluate and select the most appropriate CIS and to guide CSR on how to improve the overall CIS during the trust period. In addition, the study showed that decision makers can choose an appropriate weight according to their needs and preferences to make an appropriate decision. [8]

VIKOR is an example of a new MCDM approach used by researchers. According to Zardari et al. [9]this method is either individually preferred according to the characteristic PCS applied to decision problems in subfields such as selection, ranking, evaluation, or combined with other models according to Chiang, (2009) Like AHP and ANP. [10]

A review of service selection for cloud computing using MCDM methods discussed by Whaiduzzaman et al. does not use quantitative confidence estimates to rank various CSPs. [11]

Ruby et al. compared the performance of three cloud render farm services using AHP and SAW, and found that there is a ranking value based on the weights assigned to each QoS attribute, as in figure 4. [12]

However, both AHP and SAW have similar rankings for each discussion criterion, and ranking values are very close to each other. For this reason, the SAW method is a good alternative to AHP and may be preferred to AHP, if there is no hierarchy of qualifications as in the case discussed in this study. However, if there are many levels of hierarchy with subordinate attributes, AHP is considered as a better way to find the aggregate ranking value.

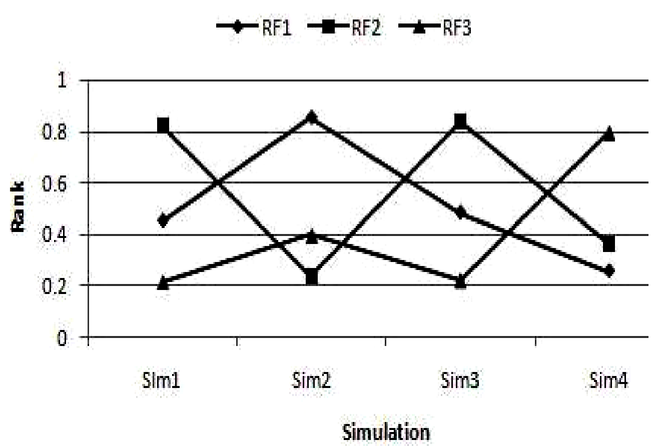


Figure 1-4 : The CSPs ranking due the QoS attributes [12]

Supriya et al. used the MCDM methods to build a trust evaluation rank for many CSPs provide Iaas services. The CSPs ranked by their Performance, Finance and Security criteria. The AHP, fuzzy AHP, the used methods are fuzzy TOPSIS and TOPSIS. Their study according to the used data showed that “Fuzzy-TOPSIS based ranking mechanism is consistent in ranking the service providers by capturing the information precisely from the infrastructure parameters. It also reduces the computational complexity and brings higher variance in the trust estimates, thus facilitating the choice of the best service provider suitable to users' priority". The study just included tow method types from the MCDM method, and didn't give importance to the new MCDM methods like "VIKOR". [13]

Hence as above mentioned there are many researchers tried to apply one or more MCDM methods in evaluation the different CSPs service types, a few of them focused on the IaaS services provided from the different providers, not all of them applied the methods practically on a real data for a real providers, and used the quantitative and qualitative confidence estimates to rank various CSPs

This study will discuss each of the six above mentioned MCDM methods (as in the next section), where each one of them will be explained in details to understand the internal algorithm for it. Each method will be used to rank four CSPs providing IaaS services:

15. Rackspace,
16. Gogrid,
17. Amazon EC2,
18. Cloudflare.

The above four CSPs have various plans, these plans have been abbreviated as: CSP1, CSP2... CSP7.

The ranking will done due the following criteria groups: agility, finance, Performance, Usability, where in the methodology section each discussed CSP will be declared (a brief description for each CSP will be presented) and each criteria will be explained.

Each CSP will be given an evaluation according to each criteria, this study benefits from the evaluation degrees which mentioned in Supriya et al. study [13]

The evaluation table will be used by each MCDM method to rank the CSPs, at the research end a comparison between the different methods results will be done to know the most consensual result, and to understand the ability to use MCDM methods in solving complex decision problems.

1.3 MCDM

Multi choices decisions consider from the most complex decisions, where in general most of the decision making problems were depend on one choice or dimension or goal function, like maximize the profit or minimize the costs. But in real life the problems don’t just depend on just one goal but on many goals; due that we need a methods that solve the multi choices decisions problems.

The complex situation for the MCDM comes from many criteria:

19. The shortage in the enough information that related with the problem
20. The different criteria
21. complex defining the criteria importance according to others

So the MCDM represents the concepts, tools and models that allow to solve the faced problem, with take in the consideration the heterogeneity between the criteria.

1.4 MCDM STEPS

The MCDM include the following steps: [14]

1.4.1 Identify alternatives

The alternatives are the group of suggestions that the decisions will built on them, and represent all the possible solutions. Where formatting the alternatives group done due to the decision goal (for example to build a university the alternatives are the locations). And the alternatives most be clear and each one represent an entity by itself.

1.4.2 Define criteria

The criteria represent all the viewpoints that effect on the suggested decisions; and represent the needs and the goals which should be in the alternative; defining the criteria is the process of collecting the enough and necessary information about the expected performance for the alternative, the criteria should be formulated by quantitative or qualitative mathematical forms; and should not be incomplete or repeated in many names under the same meanings

1.4.3 Define the criteria's weights

Each criteria has a different importance and effect on the decision making, for that a weight should be given to each criteria to represent its importance, the weight can be a percentage or number. In fact giving the weight on of the complex challenge in the MCDM, because of the self-preferences and the self-impact of the evaluator.

1.4.4 Selection the method to evaluate alternatives

There are many methods used in the MCDM (discussing in the next section)

1.4.5 Evaluate alternatives against criteria

The MCDM methods help to rank the alternatives and give the decision makers a viewpoint about the appropriate of each alternative according criteria

Validate solutions against problem statement

1.5 METHODS

As mentioned above MCDM method using to get the optimize solution for a decision problems with multiple criteria, actually MCDM a ranking approach, where it helps to rank group of alternatives based on multiple criteria values due to the most ability of this alternative to do the task; the criteria values (or weight) put by the experts in the field where not all of the criteria have the same importance.

In following the sixth most important MCDM methods (ANP, AHP, VIKOR, ELECTRE, PROMETHEE and TOPSIS) will be explained to understand the mechanism of each method and how can we use it to rank the alternative to solve our problem later.

1.5.1 AHP Method

The Analytic Hierarchy Process (AHP) invented from Thomas L. Saaty in the 1970s, it's the important MCDM method, where it's a structured technique help to give answers to the complex decisions. [1]

This theory is the most prevalent method in the world in the MCDM, for many reasons, especially for the existence of a computerized program through which the application of the theory and the construction of hierarchical forms, Sensitivity analysis and draw conclusions in a simplified and effective manner, also the principle of hierarchical analysis is generally An easy and close principle for the logical thinking of normal people. [15]

Defined as An integrated framework combining objective and non-objective standards Objectivity and pairwise comparisons based on a relative measure; and in another definition Theory of building indicators using pairwise comparisons that support the opinion of experts and decision makers within a specified scale. [15]

Fülöp define it as following “The methodology of AHP is based pairwise comparisons of the following type 'How important is criterion Ci relative to criterion Cj?' Questions of this type are used to establish the weights for criteria and similar questions are to be answered to assess the performance scores for alternatives on the subjective (judgmental) criteria”. [14]

So the main goal of the AHP is to rank a group of alternatives having group of criteria, by using preferences between alternatives and criteria through pairwise comparisons..

The process of AHP provides an effective practical structure that impose a system commitment to the intellectual process of the DM

1.5.1.1 AHP Steps

The process of AHP begins by putting the problem elements in a pyramid, comparing between the problem’ elements even in one level based on criteria, we get from these the Comparisons of priorities, Finally, we reach the overall priorities, in this way the index of stability and index of Interference between elements have been calculated as consistency index.

The Input for the AHP method can be the measurable criteria such length, depth, number of …, and the subjective criteria such agility, usability...

There is no fixed base for building hierarchical forms, and hierarchical construction depends on the type of decision to be taken. Where we can start from the end level by putting all the alternatives in it, the next level will consist from the criteria which will be used to judge the alternatives; the upper level will be the goal of our decisions making problem that we want to reach,as we see in figure (5): [1]

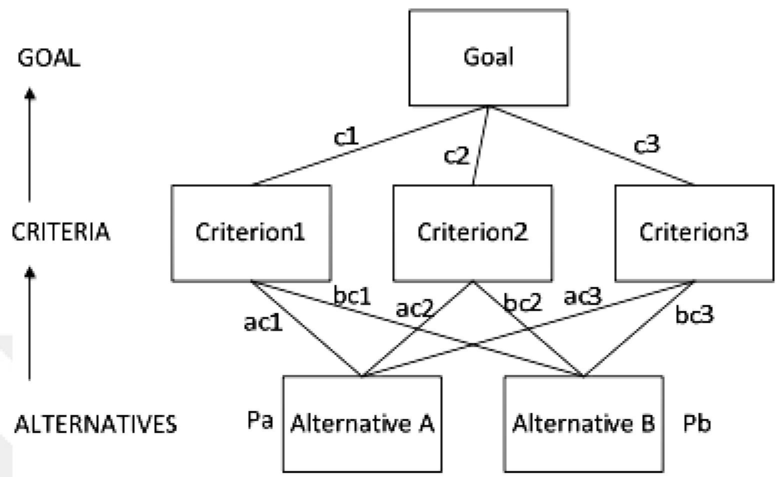


Figure 1-5 : The structure of AHP [1]

AHP involves ten steps, as follows: [3]

22. Define the main goal of your decision problem.
23. Structure elements of the decision problem in groups of criteria, alternatives.
24. Construct a pairwise matrix.
25. All criteria are compared one-to-one with the other criteria.
26. Normalizing matrix weights.
27. Each weight is divided by the sum of all weights in each matrix column.
28. Deriving a priority vector
29. The sum of each row of normalized weights gives a priority vector.
30. Calculating a maximum Eigen value vector.
31. The product of the pairwise matrix (step 3) and the priority vector (step 5).
32. Calculating the consistency index.
33. The sum of the values in a maximum Eigen value vector is subtracted by the number that represents the size of the comparison matrix.
34. Calculating the Consistency Ratio (CR).
35. The consistency ratio is calculated by dividing the consistency index (CI) by the random consistency index. A consistency check is made to see if the ratio is smaller than 0.1. If

the value of consistency ratio is smaller or equal to 0.1, the inconsistency is acceptable. If the inconsistency ratio is greater than 0.1, there is need to revise the subjective judgment.

36. Evaluate the criteria and alternatives with respect to the weighting.
37. Get ranking.

In order to achieve the goal, the elements in the hierarchy are compared in pairs according to a higher level element. Standard scales are used in the comparison process. The reason for this is the complexity of interpreting the numbers used in measurement scales. To address this problem, all measurements in the Analytic Hierarchy Process are made on the basis of the scale, also The relative importance between two criteria is measured according to a numerical, called "1 to 9 scale", which was developed by Thomas L. Saaty. [1]

Value of a_{jk}	Interpretation
1	j and k are equally important
3	j is slightly more important than k
5	j is more important than k
7	j is strongly more important than k
9	j is absolutely more important than k

Figure 1.6 : Table of relative scores**. [1]**

The calculation for CR is made with the equation CR = CI / RI. The CI consistency index is expressed here, and the RI is expressed as the random coherence index ,

$$\text{where } CI = \frac{\lambda - n}{n-1} \quad \text{and } \lambda = \frac{\sum_{i=1}^{n} \mathrm{E}_i}{n} \tag{1.1}$$

The values of RI are calculated by hourly (1980) and are called random index. RI values specify by number of criteria. [1]

Chart: RI values by number of criteria.

n	1	2	3	4	5	6	7	8	9	10	11	12	13
RI	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1.48	1.56

1.5.1.2 Advantages to the AHP method

There are many advantages to the AHP method [1] :

1. A practical way to deal quantitatively with different types of functional relationships in a complex network.

2. A powerful tool to integrate expected planning and planning in a vital way that reflects the provisions of all management personnel.

3. A new way to:

    38. Integrate clear data with substantive provisions on intangible factors.
    39. Combine the judgments of several individuals and resolve differences between them.
    40. Sensitivity analysis and audit tool at low cost.
    41. Strengthen management capacity to make concessions clearly.

4. A tool that supplements other tools (benefit / cost, priorities, risk reduction) to select projects or activities.

5. Alternative to a range of methods of future forecasting and risk protection in the uncertainty situation

6. A tool to guide the organizational achievement towards a set of critical objectives.

7 Combining the overall and partial method in a convincing frame. The overall way representing by building a pyramid in it All the elements are seen as an integrated whole. The ability to decompose the problem to connected elements helps to explain the problem to other people easily. While the partial method looks at the examination of parts of by pairwise comparisons

8. The method comprehensive the quantitative and qualitative aspects together. The qualitative aspects representing by defining the problem with its hierarchical structure, the definition of objectives and standards, while the quantitative aspects by representing the priorities in the numbers.

9. Combining objectivity and objectivity, they are objective through arrays and extraction Priorities, and subjective where it follows the decision-makers interests and preferences when making comparisons

10. The ability of this method to interact well with both simple and complex problems

11. The simplicity of the hierarchical analysis model, its flexibility, its ability to review and the diversity of its applications.

12. It does not require a previous specialization to build the model, and there is a tool aims to facilitate and make calculations accessible to all, besides the ability to implement the method in Excel sheet by writing some equations and using some functions.

1.5.1.3 AHP disadvantage

1. Decomposing the problem into number of subsystem and making the pairwise comparisons between all the elements, that lead to large number of pairwise comparisons which length the task and consuming resources. [4]

2. the used scale that we measure each alternative comparing to others in AHP is between 1 to 9, that is not very flexible where sometimes the DM don't know if an alternative is 4 or 5 more important than another one. Also sometimes there are alternative important 20 times comparing with other . [4]

1.5.2 ANP Method

The Analytic Network Process a more generalized model of the AHP. invented By Thomas L. Saaty in 1996. [17]

The method of network analysis is one of the methods of multivariate analysis that uses the structure of network to model the problem and the pairwise comparisons to make the relationships in the structure

The ANP rank the group of alternatives which have number of criteria. There are a preferences established between the criteria and alternatives done by the pairwise comparisons. The alternative which ranked as the best by this method is the most suitable one for the DM.

The structure of ANP consists of clusters and nodes, each cluster contains many nodes the nodes are connected together in the both directions as we see in the figure (6); each cluster includes one of the problem elements, where one includes the problem goals, one the alternatives, and another the criteria. Where grouping the nodes in a cluster is one of the differences between ANP and AHP. [17] Where it helps not just to compare priorities between nodes but also between clusters.

The ANP network are representing in a Matrix contains all the nodes vertically and horizontally and each non-zero element of the matrix represent the weight and connection from a node horizontally to other node inside the network vertically, this matrix after preparing are called super matrix, which contains all the related important for node to other nodes or cluster other clusters.

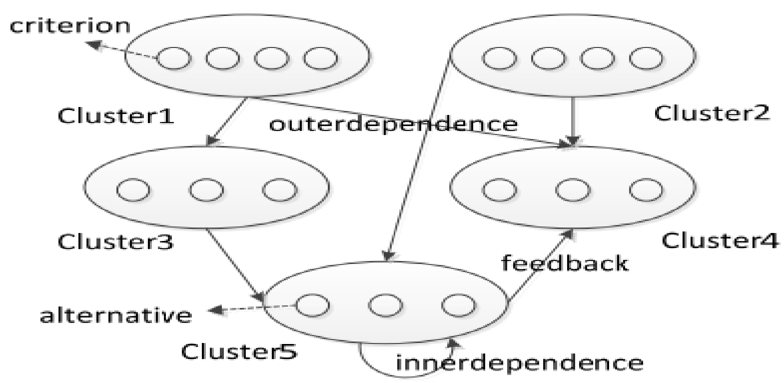


Figure 1-6 : The structure of ANP [17]

As in AHP method the nodes or clusters' pairwise comparison and calculation of local priorities are the same. Local priorities result from the pairwise comparison matrix' Eigen vector, found priorities are then structured in the super- matrix as column vectors. Un-weighted Super Matrix got after all the comparisons have done. From here and by squaring the matrix we can get the alternatives ranking as the AHP method, to transfer to the ANP we need to take into consideration the alternatives impact on the criteria importance, we normalize the matrix to get the weighted Super Matrix. Then calculating the limit matrix to synthesize the model, which is converges weighted super matrix, the final result is alternatives ranking. (More details in the algorithm description)

1.5.2.1 ANP Steps

ANP algorithm involves the following steps [17]:

Step 1 - Determination Problem: here the current problem is identified. Criteria of decision making problem sub-criteria and alternatives are determined.

Step 2 - Determination of Relations with criteria: The interactions of the specified criteria with each other, the internal and external interactions of each criteria, and the existing feedback are associated with this step. The opinions of experts are taken and the literature about the current problem is searched.

Step 3 - Performing Binary Comparisons between Criteria: As in the Analytic Hierarchy Process, pairwise comparison is made between each Criteria that is considered to be related to each other. These pairwise complements are aggregated into a resultant matrix.

Step 4 - Checking Whether the Comparison Matrices Are Consistent: A consistency analysis is performed to see if the comparisons made in this step are meaningful. After the comparison values are given, the consistency rate symbolized as CR for each matrix is calculated.

Step 5 - Generating Super Matrices in Order: In this step, inter-criterion evaluations are summarized under a large matrix under the name non-weighted super matrix. Then, multiplying the resultant super-matrix with the weighted values for corresponding clusters in the super-matrix. Taken to the (2K+1) power , (K is arbitrary number)

Step 6 - Determination and Selection of the Best Alternative: It is possible to make a comparison between the limit mathematical alternatives to see best alternative. greatest value here represents the best alternative.

The AHP is a kind of network, it follows the up down model, where the work start from the goal cluster to the alternatives according to criteria, so its downward hierarchy, in contrast the ANP method is going in the tow ways, where it not just study the criteria impact on alternatives, but also it take on the consideration the alternative impact on the decision making .which represent the real case which faced in the real life.. [16]

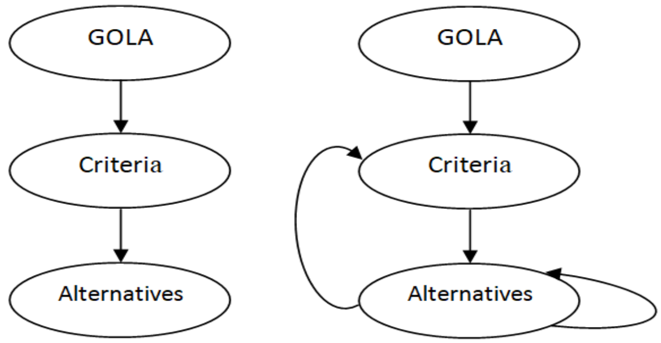


Figure 1-7 : Difference in structure between AHP (left) and ANP (Right). [16]

1.5.2.2 Advantages:

As mentioned above one of the advantages for the ANP method is that the two directions links from the nodes to the clusters , which help to deal with complicated problem in the real life. Also it help to understand our problem and the interactions between the elements better. [16]

1.5.2.3 Disadvantages:

42. In the ANP method a n(n-1)/2 pairwise comparisons are performed, which in turn make the comparison process more complicated and power consuming, for that a limited alternatives numbers and criteria should use; recommended number in cluster is less than five alternatives and criteria. [16]
43. Users tend to make the decision according the importance, it's hard to conceive the DM to make another pairwise comparison between items to reconsider their inputs, especially if the consistency index for the alternative ranking is too high. [16]
44. It's hard to apply the ANP method in Excel, so its needs a special software to implement the method. [16]

1.5.3 TOPSIS Method

The TOPSIS method a MCDMA method was developed by Yoon and Hwang in 1981. TOPSIS method using in many areas such as risk analysis, finance, plant site selection, resource planning, transportation, market selection, public sector chemical engineering etc. The results achieved by it are very real. It's used to rank alternatives through a finite criteria number. TOPSIS method care about the alternatives distances from the negative-ideal and positive ideal solution.[22]

The most important properties in the TOSIS method are the ideal solution and its negative where: [22]

• The greatest gain but the least cost solution is the ideal.

• The solution which maximizes costs while minimizing gains is negative ideal solution.

• The best values that can be assigned to criteria in the definition of the ideal solution are taken into account.

• The negative ideal solution contains the worst values that can be assigned to the criteria.

• Optimal alternative is the nearest ideal solution and the farthest alternate is the negative ideal solution

1.5.3.1 TOSIS Steps

TOSIS method involves the following steps: [22]

Step 1 – normalizing the decision matrix. The normalized decision matrix done using the formula

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}} \quad \textit{for } i=1,\ldots\ldots,m;\ j=1,\ldots\ldots,n; \qquad (1.2)$$

Where X_{ij} are original values and r_{ij} are normalized values.

The normalized decision matrix will show as following:

$$R_{ij=}\begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1n} \\ r_{21} & r_{22} & \cdots & r_{2n} \\ . & . & . & . \\ . & . & . & . \\ . & . & . & . \\ r_{m1} & r_{m2} & . & r_{mn} \end{bmatrix}$$

Step 2 - creating the weighted normalized decision matrix, regarding the importance of criteria by the formula $v_{ij} = w_j\, r_{ij}$ when w_j is the j criterion weight.

The weighted normalized decision matrix will show as following:

$$v_{ij}=\begin{bmatrix} w_1r_{11} & w_2r_{12} & \dots & w_nr_{1n} \\ w_1r_{21} & w_2r_{22} & \dots & w_nr_{2n} \\ . & . & . & . \\ . & . & . & . \\ . & . & . & . \\ w_1r_{m1} & w_2r_{m2} & . & w_nr_{mn} \end{bmatrix}$$

Step 3 - Determining the negative and positive ideal solutions. Positive ideal solution is given by the following formula

$$A^* = \left\{\left(\max_i v_{ij} \mid j \in J\right), \left(\min_i v_{ij} \mid j \in J'\right) \mid i = 1,2, \dots\dots, m\right\}$$

$$A^* = \{v_1^*, v_2^*, \dots., v_j^*, \dots, v_n^*\}$$

The negative ideal solution is:

$$A^* = \left\{\left(\min_i v_{ij} \mid j \in J\right), \left(\max_i v_{ij} \mid j \in J'\right) \mid i = 1,2, \dots\dots, m\right\}$$

$$A^* = \{v_1^*, v_2^*, \dots., v_j^*, \dots, v_n^*\}$$

Where J= { j= 1,2, …, n / j associated with benefit criteria }

Where J'= { j= 1,2, …, n / j associated with cost criteria }

Step 4 - Calculating the separation from the negative and the separation from the positive ideal alternative. The following formula used to calculate the separation from the positive ideal

$$S_i^* = \sqrt{\sum_{i=1}^{n}\left(v_{ij} - v_j^*\right)^2} \quad i=1,2,\dots..,m \tag{1.3}$$

And the separation from the negative ideal solution is given by formula

$$S_i' = \sqrt{\sum_{i=1}^{n}\left(v_{ij} - v_j'\right)^2} \quad i=1,2,\dots..,m \tag{1.4}$$

Step 5 - the closeness coefficients are calculated.

$$c_i^* = \frac{S_i'}{(S_i^* + S_i')} \quad , 0 < c_i^* < 1 \, , i = 1,2, \ldots , m \qquad (1.5)$$

$$c_i^* = 1 \qquad if \;\; A_{i=}A^*$$

$$c_i^* = 0 \qquad if \;\; A_{i=}A'$$

The descending order used to rank the alternatives by the closeness coefficient values, the solution with higher value is the better.

1.5.3.2 Advantages

1. . TOPSIS method supports quantitative values.

2. Simple in using and implementing. For that it used widely in many life problems.

3. There are many tools support it.

1.5.3.3 Disadvantages

The missing values or the uncertain is not supported in this method [22].

1.5.4 ELECTRE Method

ELECTRE means the elimination and selection that reflects the truth. Firstly Benayoun, by Roy and his friends in 1966 developed. As a response to existing decision making methods developed. In fact, it is not just a solution method is a debated philosophy. The main concept of the ELECTRE method; for each criterion is to use dual comparisons between alternatives. For each rating factor, it is based on binary superiority comparisons between alternative decision points. Where two alternatives are compared in a time and selects the one which is better in most criteria and not acceptably worse in other criteria. ELECTRE method a multi-purpose decision making technology used. [24]

1.5.4.1 ELECTRE Steps

There are steps of ELECTRE as : [23]

Step 1 - Preparation of Decision Matrix

Step 2 - Calculate the normalized decision matrix.

It will be normalized using the following formula:

$$x_{ij} = \frac{r_{ij}}{\sqrt{\sum_{i=1}^{n} r_{ij}^2}} \quad \textit{for i=1,........,m ; j=1,........,n;} \tag{1.6}$$

The normalized matrix will be as following:

$$X_{ij=} \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1n} \\ x_{21} & x_{22} & \cdots & x_{2n} \\ . & . & . & . \\ . & . & . & . \\ . & . & . & . \\ x_{m1} & x_{m2} & . & x_{mn} \end{bmatrix}$$

Step 3 - Calculate the weighted normalized decision matrix.

$$Y_{ij=} \begin{bmatrix} w_1 x_{11} & w_2 x_{12} & \cdots & w_n x_{1n} \\ w_1 x_{21} & w_2 x_{22} & \cdots & w_n x_{2n} \\ . & . & . & . \\ . & . & . & . \\ . & . & . & . \\ w_1 x_{m1} & w_2 x_{m2} & . & w_n x_{mn} \end{bmatrix}$$

Step 4 -Determine the discordance and concordance set.

Y matrix used to determine the concordance sets. Decision points are compared with each other in terms of evaluation factors. Net weighted normalized matrix data is compared for every pair and results are evaluated as below: If alternative is better than or equal to other element of pair it is considered under concordance set and defined by C. sets is determined by the relationship shown in the form:

$$C_{kl} = \{j, y_{kj} \geq y_{lj}\}$$

The formula is based on the size of the line elements relative to each other based on comparison.

If alternative is worse than the other element of the pair for relevant criteria it is considered under discordance set and defined by D .The discordance set can be calculate as following:

$$D(p,q) = \{j, v_{pj} < v_{qj}\}$$

Step 5 -Calculate the concordance matrix.

Concordance matrix is the matrix generated by adding the values of weights of Concordance set elements.

$$C_{pq} = \sum_{j^*} w_j \tag{1.7}$$

$$C_{ij=}\begin{bmatrix} \_ & c_{12} & c_{13} & \cdots & c_{1m} \\ c_{21} & \_ & c_{23} & \cdots & c_{2m} \\ . & & & & . \\ . & & & & . \\ . & & & & . \\ c_{m1} & c_{m2} & c_{m3} & \ldots & \_ \end{bmatrix}$$

Step 6 -Calculate the discordance matrix.

Discordance matrix is prepared by dividing discordance set members values to total value of whole set.

$$D_{pq} = \frac{\left(\sum_{j^0} \left|v_{pj^0} - v_{qj^0}\right|\right)}{\left(\sum_j \left|v_{pj} - v_{qj}\right|\right)} \tag{1.8}$$

$$D_{ij=}\begin{bmatrix} \_ & d_{12} & d_{13} & \cdots & d_{1m} \\ d_{21} & \_ & d_{23} & \cdots & d_{2m} \\ . & & & & . \\ . & & & & . \\ . & & & & . \\ d_{m1} & d_{m2} & d_{m3} & \ldots & \_ \end{bmatrix}$$

Step 7- Make calculations of advantage Averages of concordance and discordance values are taken. In the Concordance matrix any C_{pq} value bigger than or equal to C average it is stated as yes. In the discordance matrix any value less than or equal to D average is stated as No.

Step 8 -Calculate net concordance and discordance matrix

The best alternative is the one that dominates all the other alternatives in this manner.

To make the rank between alternatives we calculate the net concordance and net discordance values, we use the following formulation:

$$C_k = \sum_{\substack{l=1 \\ l\neq k}}^{m} C_{kl} - \sum_{\substack{l=1 \\ l\neq k}}^{m} C_{lk} \quad (1.9)$$

$$d_k = \sum_{\substack{l=1 \\ l\neq k}}^{m} d_{kl} - \sum_{\substack{l=1 \\ l\neq k}}^{m} d_{lk} \quad (1.10)$$

1.5.5 VIKOR Method

VIKOR (VIseKriterijumsa Optimizacija I Kompromisno Resenje) method has been proposed by Serafim Opricovic in 1998 to deal with very complex decision problems. The method used in many fields. [26]

Offers compelling solutions for problems with contradictory criteria, focusing on sorting and selecting alternatives. To reach final decisions. Best alternative solution is the most close solution to ideal, and best alternative is reaching agree on mutual acceptance. [25]

1.5.5.1 VIKOR Steps

In the following the VIKOR method steps: [26]

Step 1 - for each criterion (i = 1,2, ..., n) ,alternatives (J = 1, 2, ..., J) we need to calculate the worst and the best alternative for each criterion:

If the i criterion represents utility we calculate as following:

$$f_i^* = max_i f_{ij} \qquad f_i' = min_i f_{ij} \quad (1.11)$$

If the i criterion represents cost we calculate as following:

$$f_i^* = min_i f_{ij} \qquad f_i' = max_i f_{ij} \quad (1.12)$$

Step 2 - to each alternative, the following formula used to calculate the ideal value S_j (or benefit measure) and the negative value R_j (or regression measure:

$$S_i = \sum_{i=1}^{n} \omega_i \cdot \frac{(f_i^* - f_{ij})}{(f_i^* - f_i^-)} \qquad R_j = \max_i \left[\omega_i \cdot \frac{(f_i^* - f_{ij})}{(f_i^* - f_i^-)}\right] \quad (1.13)$$

when j=1,…m also i=$1,…n$

ω_i : Expresses criteria weights indicating relative importance. The sum of the weights will be equal to 1.

Step 3 - Calculate the synergy value Q_j for each alternative using the following equations:

$$Q_j = v\,\frac{(S_j - S^*)}{(S^- - S^*)} + (1-v)\frac{(R_j - R^*)}{(R^- - R^*)} \quad , \qquad \begin{matrix} S^* = min_j\ S_j\ \ S^- = max_j\ S_j \\ R^- = max_j\ R_j\ \ R^* = min_j\ R_j \end{matrix} \tag{1.14}$$

when $j = 1, \dots, \dots, m$ also $i = 1, \dots, \dots, n$

v expresses the weight of the maximum group benefit, 1-v the weight of personal regret [25]. v is generally taken as 0.5

Step 4 - S, R and Q are sorted from small to large. S, R, and Q values are sorted in their own order to obtain three different orders

Step 5 - The alternatives A (1) represents the best ordered solution in the order of decreasing order by the measured values S, R and Q and then Q (minimum).

When the proposed solution is proposed, two conditions must be fulfilled:

a. Acceptable advantage

$$Q(A^{(2)}) - Q(A^{(1)}) \leq DQ\ where\ DQ = \frac{1}{m-1} \tag{1.15}$$

* A (2) indicates the second best alternative, m : the number of alternatives

b. Acceptable stability when making a decision - the recommended alternative (1) should be ranked by S and / or R best.

If one of these two conditions cannot be met, then the agreed-upon common best solution set is proposed as follows:

Alternatives (1) and A (2) if condition (B) is not met. (A) are not fulfilled, the alternatives A (1), A (2)... A (m); A (m) is the maximum for the relationship to M, is determined by:

$$Q\left(A^{(M)}\right) - Q\left(A^{(1)}\right) < DQ$$

1.5.6 PROMETHEE Method

PROMETHEE (Preference Ranking Organization METHods **E**nrichement **E**valuation) the method suggested by Jean-Pierre Brans in 198.

Its considered from Partial Aggregation Methods, This method is able to evaluate a large set of alternatives based on a large set of criteria as a classification of these alternatives according to the priority and importance, and it was classified as one of the most efficient MCDM methods. The goal of the PROMETHEE method is to classify the alternatives from the most important to the least, so that each standard has a quantitative weight and each alternative has its own evaluation for this criterion; weights and ratings are used to calculate this compound preference index that determines how preferable one alternative is to another. [27]

The PROMETHEE built on three axioms: [27]

1) Examination: if tow alternatives have the same estimation for each criterion, then the decision maker see the neutrality between these alternatives.

2) Cohesion: if alternative a better than alternative b for each criterion, then a is better than b in the final result

3) Non-Redondance: a criterion is non-redondance if deleting it prevented the criteria group from achieving the previous axioms

The procedure of the PROMETHEE method consists of several steps: [27]

Step 1 - The pairwise comparison for each tow alternatives according to each criterion:

In general there are four relations types between alternatives: [27]

45. Indifference: there are a clear reasons explain the neutrality between two alternatives.
46. Preference Stricte: there are a clear reasons explain the superiority for one alternative comparing the other.
47. Poor preference: there are a clear reasons eliminate the superiority for one alternative comparing the other.

48. Incomparability: where there are none of the previous relation exists we take this relation.

The evaluation table is represent the main base in PROMETHEE method, where it contains the alternatives, criteria, weights, thresholds, as in the following table (the table is taken from the main interface for “visual PROMETHEE” application) : [29]

Table 1-1 : The evaluation table

Criteria	G1	G2	……	G n
preferences				
Weights	W1	W2	……	W n
Preference function				
Thresholds	P1	P2	……	Pn
	Q1	Q2	……	Qn
	S1	S2	……	Sn
Alternatives				
A1	G1 (a1)	G2 (a1)		Gn (a1)
Am	G1 (am)	G2 (am)		Gn (am)

Criteria and alternatives discussed previously

Weights: are the importance of each criterion according others

Thresholds: determined by the decision makers, where there are three types: P, Q, and S

49. Indifference threshold “Q”: it’s the max value that keep the decision maker neutral from choosing one between two alternatives.
50. Preference threshold “P”: the min value that make the decision maker prefer one alternative between two.

51. $\min\left|d_j(a,b)\right| \leq q \leq p \ \leq \max\left|d_j(a,b)\right|$ (1.16)

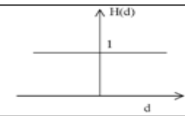
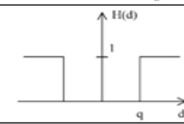
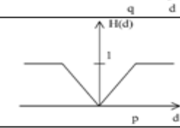
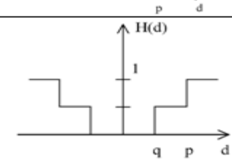
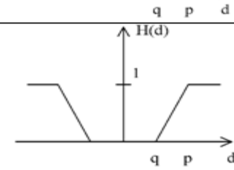
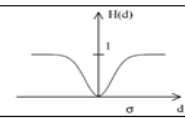
where : $S_i\ d_j\ (a,b) < Q \Longrightarrow P_j(a,b) = 0$

$S_i\ d_j\ (a,b) > P \Longrightarrow P_j(a,b) = 1$

52. d_j(a, b) represents the difference between two values a, b according to criterion g where : d_j (a, b)= g_j (a) - g_j(b)
53. $g_j(a)$: represent the estimation for the alternative (a) according to criterion (g)
54. $g_j(b)$: represent the estimation for the alternative (b) according to criterion (g)
55. $d_j(a,b)$: the difference function which represent the preference between (a) and b according to (g)
56. Gaussian threshold “S”: If the difference between evaluating two alternatives is greater than this threshold, the decision-maker avoids the alternative that contributed to this neutrality

To select the preference function we have 6 criteria: [28]

Table 1.2 : Preference functions criteria

Type of genera- lazed criteria	Analytical definition	Shape	Parameters to define
Type I. Usual criterion	$H(d)=\begin{cases}0, & d=0;\\1, & \lvert d\rvert>0.\end{cases}$		--
Type II. Quasi-criterion	$H(d)=\begin{cases}0, & \lvert d\rvert\le q;\\1, & otherwise.\end{cases}$		q
Type III. Criterion with linear preference	$H(d)=\begin{cases}\frac{\lvert d\rvert}{p}, & \lvert d\rvert\le p;\\1, & \lvert d\rvert>0.\end{cases}$		p
Type IV. Level-criterion	$H(d)=\begin{cases}1, & \lvert d\rvert\le q;\\1/2, & q<\lvert d\rvert\le p;\\1, & otherwise.\end{cases}$		q, p
Type V. Criterion with linear preference and indifference area	$H(d)=\begin{cases}1, & \lvert d\rvert\le q;\\\frac{\lvert d\rvert-q}{p-q}, & q<\lvert d\rvert\le p;\\1, & otherwise.\end{cases}$		q, p
Type VI. Guassian criterion	$H(d)=1-\exp(-\frac{d^2}{2\sigma^2})$		σ

Step 2 - For each couple of actions a, b E- K, we first define a preference index π for a with regard to b over all the criteria. Suppose every criterion has been identified as being of one of the six types considered so that the preference functions $P_h(a, b)$ have been defined for each h = 1, 2, ..k.

we suppose here that all the criteria have the same importance. If it is not the case, one can introduce a weighted preference index. As following: [30]

$$\pi(a, b) = \frac{1}{k}\sum_{h=1}^{k} P_h\,(a, b) \qquad (1.17)$$

Step 3- calculate the flows: [27]

57. Outgoing flow

58. $phi^{+}(a) = \frac{1}{n-1}\sum_{x\in A}\pi(a, x)$ (1.18)

59. Incoming flow

60. $phi^{-}(a) = \frac{1}{n-1}\sum_{x \in A} \pi(a,x)$ (1.19)

61. Net flow

62. $phi(a) = phi^{+}(a) - phi^{-}(a)$ (1.20)

Step 4- ranking alternatives [27]

63. PROMETHEE I ranking: alternative a preferred if $phi^{+}(a)$ is large and $phi^{-}(a)$is small

64. PROMETHEE II ranking: alternative a preferred on b if phi (a) > phi (b)

2. METHODOLOGY

2.1 PROBLEM DEFINITION

This study discussing the problem of ranking seven CSP plans as alternatives to provide the IaaS in the market, these plans have been abbreviated as: CSP1, CSP2... CSP7.

The ranking of theses CSPs will done through four criteria groups: agility, finance, Performance, Usability; each criteria group contains two criteria. The following table shows the evaluation degree for each CSP according to each criteria; the table obtained from a previous study. (Supriya et al. 2016). This table will be used in each MCDM method to rank the CSPs.

Table 2.1 : Original matrix

	No. of VM	SS	No. of Pro.	RAM	VM Cost	Tra Cost	Ease.	Flex.
CSP1	8	1	8	12	0.5553	0.29	0.8	0.85
CSP2	12	0.934	12	48	1.666	0.29	0.9	0.9
CSP3	2	0.219	2	8	1.068	0.18	0.85	0.9
CSP4	6	0.6	6	32	1.694	0.18	0.87	0.9
CSP5	12	0.292	12	32	2.083	0.18	0.85	0.9
CSP6	2	0.16	2	1.7	0.06	0.2	0.9	0.84
CSP7	2	0.5	2	8	1.76	0.25	0.78	0.8

2.1.1 Alternatives

2.1.1.1 Gogrid: [19]

Big Data Multi-Cloud Pioneer, an industry leader in multi-cloud solutions for Big Data deployments. GoGrid’s proprietary orchestration and automation technologies are unique in the market, providing 1-Button deployment for Big Data solutions that speed creation and results of new cloud projects.

2.1.1.2 Rackspace: [18]

Rackspace is a set of cloud computing products and services billed on a utility computing basis from the US-based company Rackspace. Offerings include web application hosting or platform as a service ("Cloud Sites"), Cloud Storage ("Cloud Files"), virtual private server ("Cloud Servers"), load balancers, databases, backup, and monitoring.

2.1.1.3 Amazon EC2: [20]

Forms a central part of Amazon.com's cloud-computing platform, Amazon Web Services (AWS), by allowing users to rent virtual computers on which to run their own computer applications. EC2 encourages scalable deployment of applications by providing a web service through which a user can boot an Amazon Machine Image (AMI) to configure a virtual machine, which Amazon calls an "instance", containing any software desired. A user can create, launch, and terminate server-instances as needed, paying by the hour for active servers – hence the term "elastic". EC2 provides users with control over the geographical location of instances that allows for latency optimization and high levels of redundancy.

2.1.1.4 Cloudflare: [21]

Cloudflare is a U.S. company that provides a content delivery network, Internet security services and distributed domain name server services, sitting between the visitor and the Cloudflare user's hosting provider, acting as a reverse proxy for websites .

2.1.2 Criteria:

The following criteria are obtained from (Supriya et al.)' study: [13]

2.1.2.1 Agility:

Agility criteria group contains the number of virtual machines, storage space in Tera byte which provided by each CSP.

2.1.2.2 Performance:

Performance criteria group contains the number of processors, Ram in Giga byte which provided by each CSP.

2.1.2.3 Financial:

Financial criteria group contains the virtual machines' costs, transfer costs (GB/$) which provided by each CSP

2.1.2.4 Usability:

Usability criteria group contains the easability, flexibility which provided by each CSP

The criteria group and its attributes will be as following:

Table 2.2 : Criteria groups

Agility	The number of virtual machines (No. of VM)	Storage space (SS)
Performance	Number of processor (No. of Pro.)	RAM (GB)
Financial	Virtual machine cost (VM Cost)	Transfer Cost (Tra Cost)
Usability	Easability (Eas.)	Flexibility (Flex.)

As table shows the criteria are: quantifiable and non-quantifiable, the evaluation for each CSP according to quantifiable criteria will got from the infrastructure attributes for each CSP; where the evaluation for each CSP according to non-quantifiable criteria will got from like Usability obtained from a survey.

2.2 PROBLEM SOLVING

2.2.1 Solution of Problem with AHP Method

We have the following decision matrix:

Table 2.3 : Original matrix

	No. of VM	SS	No. of Pro.	RAM	VM Cost	Tra Cost	Ease.	Flex.
CSP1	8	1	8	12	0.5553	0.29	0.8	0.85
CSP2	12	0.934	12	48	1.666	0.29	0.9	0.9
CSP3	2	0.219	2	8	1.068	0.18	0.85	0.9
CSP4	6	0.6	6	32	1.694	0.18	0.87	0.9
CSP5	12	0.292	12	32	2.083	0.18	0.85	0.9
CSP6	2	0.16	2	1.7	0.06	0.2	0.9	0.84
CSP7	2	0.5	2	8	1.76	0.25	0.78	0.8

The following table got by normalizing the matrix by using the following formula:

$$R_{ij} = A_i / \sum_{j=0}^{m} Aj \qquad (2.1)$$

Table 2.4 : Normalized matrix

	No. of VM	SS	No. of Pro.	RAM	VM Cost	Tra Cost	Ease.	Flex.
CSP1	0.18182	0.26991	0.18182	0.08469	0.06249	0.18471	0.13445	0.13957
CSP2	0.27273	0.25209	0.27273	0.33874	0.18748	0.18471	0.15126	0.14778
CSP3	0.04545	0.05911	0.04545	0.05646	0.12019	0.11465	0.14286	0.14778
CSP4	0.13636	0.16194	0.13636	0.22583	0.19063	0.11465	0.14622	0.14778
CSP5	0.27273	0.07881	0.27273	0.22583	0.23441	0.11465	0.14286	0.14778
CSP6	0.04545	0.04318	0.04545	0.012	0.00675	0.12739	0.15126	0.13793
CSP7	0.04545	0.13495	0.04545	0.05646	0.19806	0.15924	0.13109	0.13136

The importance of each criterion according to other shaped in the following table:

Table 2.5 : Criterion importance for each criterion

	No. of VM	SS	No. of Pro.	RAM	VM Cost	Tra Cost	Ease.	Flex.
No. of Vm	1	0.11111	1	2.222222	0.11111	0.11111	0.14	0.14286
SS	9	1	9.090909	9	1	0.5	2	2
No. of Pro.	1	0.11	1	2.222222	0.11111	0.11111	0.14286	0.14286
RAM	0.45	0.04	0.45	1	0.11111	0.11111	0.11111	0.11111
VM cost	9	0.86	9	9	1	0.16667	0.66667	0.68966
Tra. Cost	9	2	9	9	6	1	3.7037	3.84615
Ease.	7	0.6	7	9	1.5	0.27	1	1
Flex.	7	0.6	7	9	1.45	0.26	1	1

By normalizing the previous table we got:

Table 2.6 : Normalized criterion importance

Normalization	C1	C2	C3	C4	C5	C6	C7	C8
C1	0.02301	0.020881186	0.02296691	0.04405286	0.00985	0.04392	0.01629	0.01599
C2	0.20713	0.187930674	0.20879006	0.1784141	0.08863	0.19763	0.22812	0.2239
C3	0.02301	0.020672374	0.02296691	0.04405286	0.00985	0.04392	0.01629	0.01599
C4	0.01036	0.007517227	0.01033511	0.01982379	0.00985	0.04392	0.01267	0.01244
C5	0.20713	0.16162038	0.20670216	0.1784141	0.08863	0.06588	0.07604	0.07721
C6	0.20713	0.375861349	0.20670216	0.1784141	0.53176	0.39526	0.42245	0.43057
C7	0.1611	0.112758405	0.16076835	0.1784141	0.13294	0.10672	0.11406	0.11195
C8	0.1611	0.112758405	0.16076835	0.1784141	0.12851	0.10277	0.11406	0.11195

Then the priority vector for each criterion calculated by using the following formula:

$$V_1 = \sum_{j=0}^{m} Nj \,/m \tag{2.2}$$

Where $\sum_{j=0}^{m} Nj$ is the sum of the values for each criterion (each line), and m is the criteria numbers

Table 2.7 : Criterion priority vector

priority vector	
C1	0.024621
C2	0.190068
C3	0.024595
C4	0.015864
C5	0.132703
C6	0.343519
C7	0.134839
C8	0.133791

Then the maximum Eigen value vectors calculated by sum the multiplying of each row in the comparison matrix with the priority vectors

Table 2.8 : Criteria maximum Eigen value vector

Maximum Eigen value vector
0.19687665
1.61974429
0.196665464
0.128374974
1.121293893
3.119574926
1.161760574
1.151690254

Then the element of the vectors calculated by dividing the maximum Eigen value vectors on the priority vectors

Table 2.9 : Criteria elements of the vector

The elements of the vector
7.996291895
8.52191187
7.996191395
8.092350621
8.449673754
9.081234854
8.615885287
8.608104542

Then lambda value calculated by calculating the average for the elements of the vector:

Lambda = 8.420205527

The consistency index calculated by the following formula:

$$CI = \frac{\lambda - n}{n - 1} \quad \text{Where n is the criteria numbers} \tag{2.3}$$

CI = 0.060029361

Then the Random Index value extracted from the following table. [1] Where n the criteria numbers: for 8 criteria RI= 1.41

Table 2-10 Random Index value

n	1	2	3	4	5	6	7	8	9	10	11	12	13
RI	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1.48	1.56

By dividing CI/RI we got the Consistency Ratio (CR) = 0.042574015, CR value must be <0.1 to accept to continue. [1]

In the next we repeat the previous steps but the comparison will done between alternatives in the matrix axis according to each criterion:

For the NO.VM:

The following values got by comparing the importance for each alternative due other alternative according to NO of VM in the original matrix:

Table 2.11 :"NO.VM" according alternatives comparing

No of VM	CSP1	CSP2	CSP3	CSP4	CSP5	CSP6	CSP7
CSP1	1	0.667	4	1.333	0.667	4	4
CSP2	1.5	1	6	2	1	6	6
CSP3	0.25	0.167	1	0.333	0.167	1	1
CSP4	0.75	0.5	3	1	0.5	3	3
CSP5	1.5	1	6	2	1	6	6
CSP6	0.25	0.167	1	0.333	0.167	1	1
CSP7	0.25	0.167	1	0.333	0.167	1	1

By normalizing the previous table we got:

Table 2.12 : "NO.VM" according alternatives comparing normalization

Normalization	CSP1	CSP2	CSP3	CSP4	CSP5	CSP6	CSP7
CSP1	0.1818	0.1818	0.1818	0.18181	0.18184	0.18182	0.18182
CSP2	0.2727	0.2726	0.2727	0.27278	0.27263	0.27273	0.27273
CSP3	0.0455	0.0455	0.0454	0.04542	0.04553	0.04545	0.04545
CSP4	0.1363	0.1363	0.1363	0.13639	0.13631	0.13636	0.13636
CSP5	0.2727	0.2726	0.2727	0.27278	0.27263	0.27273	0.27273
CSP6	0.0454	0.0455	0.0454	0.04542	0.04553	0.04545	0.04545
CSP7	0.0454	0.0455	0.0454	0.04542	0.04553	0.04545	0.04545

Priority vectors:

Table 2.13 :"NO.VM" according priority vector

Priority vector	
CSP1	0.18182
CSP2	0.27271
CSP3	0.04547
CSP4	0.13635
CSP5	0.27271
CSP6	0.04547
CSP7	0.04547

Maximum Eigen value vector

Table 2.14 : "NO.VM" according Maximum Eigen value vector

Maximum Eigen value vector
1.273017615
1.909321893
0.318356668
0.954660946
1.909321893
0.318356668
0.318356668

The elements of the vector

Table 2.15 : "NO.VM" according the elements of the vector

The elements of the vector
7.001392408
7.001392206
7.001393012
7.001392206
7.001392206
7.001393012
7.001393012

The alternative priorities according the NO of VM:

Table 2.16 :"NO.VM" according alternatives priority

ƛ	7.00139258
CI	0.000232097
RI	1.32
CR	0.000175831

For Space Storage (SS):

The following values got by comparing the importance for each alternative due other alternative according to SS in the original matrix:

Table 2.17 : "SS" according alternatives comparing

Space Storage	CSP1	CSP2	CSP3	CSP4	CSP5	CSP6	CSP7
CSP1	1	1	5	2	4	6	2
CSP2	1	1	4	2	3	6	2
CSP3	0.2	0.25	1	0.365	1	1	0.438
CSP4	0.5	0.5	2.73973	1	2	4	1.2
CSP5	0.25	0.33333	1	0.5	1	2	0.584
CSP6	0.16667	0.16667	1	0.25	0.5	1	0.32
CSP7	0.5	0.5	2.28311	0.83333	1.71233	3.125	1

By normalizing the previous table we got:

Table 2.18 :"SS" according alternatives comparing normalization

Normalization	CSP1	CSP2	CSP3	CSP4	CSP5	CSP6	CSP7
CSP1	0.2765	0.26667	0.29372	0.28784	0.30275	0.25946	0.26518
CSP2	0.2765	0.26667	0.23498	0.28784	0.22706	0.25946	0.26518
CSP3	0.0553	0.06667	0.05874	0.05253	0.07569	0.04324	0.05807
CSP4	0.13825	0.13333	0.16094	0.14392	0.15137	0.17297	0.15911
CSP5	0.06912	0.08889	0.05874	0.07196	0.07569	0.08649	0.07743
CSP6	0.04608	0.04444	0.05874	0.03598	0.03784	0.04324	0.04243
CSP7	0.13825	0.13333	0.13412	0.11993	0.1296	0.13514	0.13259

Priority vectors:

Table 2-19 "SS" according priority vector

Priority vector	
CSP1	0.27887
CSP2	0.25967
CSP3	0.05861
CSP4	0.15141
CSP5	0.07547
CSP6	0.04411
CSP7	0.13185

Maximum Eigen value vector:

Table 2.20 : "SS" according Maximum Eigen value vector

Maximum Eigen value vector
1.964665596
1.830584111
0.411900471
1.066862334
0.531284208
0.310256993
0.928187326

The elements of the vector:

Table 2.21 :"SS" according The elements of the vector

The elements of the vector
7.045004626
7.049681063
7.028224426
7.045971883
7.039220269
7.033765024
7.039630477

The alternative priorities according the SS:

Table 2.22 : "SS" according alternatives priority

ƛ	7.040213967
CI	0.006702328
RI	1.32
CR	0.005077521

For VM cost criterion:

The following values got by comparing the importance for each alternative due other alternative according to VM cost in the original matrix:

Table 2.23 :"VM cost" according alternatives comparing

VM Cost	CSP1	CSP2	CSP3	CSP4	CSP5	CSP6	CSP7
CSP1	1	0.3	1	0.3	0.2	5	0.3
CSP2	3	1	2	1	0.8	4	1
CSP3	1	0.5	1	0.6	0.5	6	0.5
CSP4	3.33333	1	1.66667	1	0.8	4	0.7
CSP5	5	1.25	2	1.25	1	3	0.8
CSP6	0.2	0.25	0.16667	0.25	0.33333	1	0.6
CSP7	3.33333	1	2	1.42857	1.25	1.66667	1

By normalizing the previous table we got:

Table 2-24 "VM cost " according alternatives comparing normalization

Normalization	CSP1	CSP2	CSP3	CSP4	CSP5	CSP6	CSP7
CSP1	0.05929	0.0566	0.10169	0.05147	0.04096	0.2027	0.06122
CSP2	0.17787	0.18868	0.20339	0.17157	0.16382	0.16216	0.20408
CSP3	0.05929	0.09434	0.10169	0.10294	0.10239	0.24324	0.10204
CSP4	0.19763	0.18868	0.16949	0.17157	0.16382	0.16216	0.14286
CSP5	0.29644	0.23585	0.20339	0.21446	0.20478	0.12162	0.16327
CSP6	0.01186	0.04717	0.01695	0.04289	0.06826	0.04054	0.12245
CSP7	0.19763	0.18868	0.20339	0.2451	0.25597	0.06757	0.20408

Priority vectors:

Table 2-25 "VM cost" according priority vector

Priority vector	
CSP1	0.08199
CSP2	0.18165
CSP3	0.11513
CSP4	0.17089
CSP5	0.20569
CSP6	0.05002
CSP7	0.19463

Maximum Eigen value vector:

Table 2-26 "VM cost" according Maximum Eigen value vector

Maximum Eigen value vector
0.652498175
1.388030054
0.890743931
1.31859327
1.592342393
0.359079984
1.464451027

The elements of the vector:

Table 2.27 : "VM cost" according the elements of the vector

The elements of the vector
7.958117824
7.641115439
7.736590457
7.71616631
7.741588499
7.179184723
7.524240857

The alternative priorities according the VM cost:

Table 2.28 :"VM cost" according alternatives priority

ƛ	7.642429159
CI	0.107071526
RI	1.32
CR	0.081114793

For Transfer cost criterion:

The following values got by comparing the importance for each alternative due other alternative according to Transfer cost in the original matrix:

Table 2-29 "Tra cost" according alternatives comparing

Transfer Cost	CSP1	CSP2	CSP3	CSP4	CSP5	CSP6	CSP7
CSP1	1	0.25	1.6	1.6	1.6	1.5	1.1
CSP2	4	1	1.6	1.6	1.6	1.5	1.2
CSP3	0.625	0.625	1	0.25	0.25	2	0.7
CSP4	0.625	0.625	4	1	1	3	0.7
CSP5	0.625	0.625	4	1	1	4	0.7
CSP6	0.66667	0.66667	0.5	0.33333	0.25	1	0.2
CSP7	0.90909	0.83333	1.42857	1.42857	1.42857	5	1

By normalizing the previous table we got:

Table 2-30 "Tra cost " according alternatives comparing normalization

Normalization	CSP1	CSP2	CSP3	CSP4	CSP5	CSP6	CSP7
CSP1	0.11833	0.05405	0.11325	0.22186	0.22445	0.08333	0.19643
CSP2	0.47333	0.21622	0.11325	0.22186	0.22445	0.08333	0.21429
CSP3	0.07396	0.13514	0.07078	0.03466	0.03507	0.11111	0.125
CSP4	0.07396	0.13514	0.28311	0.13866	0.14028	0.16667	0.125
CSP5	0.07396	0.13514	0.28311	0.13866	0.14028	0.22222	0.125
CSP6	0.07889	0.14414	0.03539	0.04622	0.03507	0.05556	0.03571
CSP7	0.10758	0.18018	0.10111	0.19809	0.2004	0.27778	0.17857

Priority vectors:

Table 2.31 :"Tra cost" according priority vector

Priority vector	
CSP1	0.14453
CSP2	0.22096
CSP3	0.08367
CSP4	0.15183
CSP5	0.15977
CSP6	**0.06157**
CSP7	0.17767

Maximum Eigen value vector:

Table 2.32 : "Tra cost" according Maximum Eigen value vector

Maximum Eigen value vector
1.119995043
1.737066843
0.637511105
1.183800058
1.245368868
0.473150613
1.36571187

The elements of the vector:

Table 2.33 :"Tra cost" according The elements of the vector

The elements of the vector
7.749309662
7.861476178
7.618990439
7.796848319
7.794902123
7.684907495
7.68671103

The alternative priorities according the Transfer cost:

Table 2.34 : "Tra cost" according alternatives priority

ƛ	7.741877892
CI	0.123646315
RI	1.32
CR	0.093671451

For No. of Processors criterion:

The following values got by comparing the importance for each alternative due other alternative according to No. of Processors in the original matrix:

Table 2.35 :"No. of Pro" according alternatives comparing

No. of Processors	CSP1	CSP2	CSP3	CSP4	CSP5	CSP6	CSP7
CSP1	1	0.6	0.51994	1.5	0.6	9.255	0.31551
CSP2	1.66667	1	1.55993	0.98347	0.79981	5	0.94659
CSP3	1.92328	0.64106	1	0.3	0.51272	17.8	0.60682
CSP4	0.66667	1.01681	3.33333	1	0.81325	28.2333	0.9625
CSP5	1.66667	1.2503	1.95037	1.22963	1	34.7167	1.18352
CSP6	0.10805	0.2	0.05618	0.03542	0.0288	1	0.03409
CSP7	3.16946	1.05642	1.64794	1.03896	0.84494	29.3333	1

By normalizing the previous table we got:

Table 2.36 : "No. of Pro" according alternatives comparing normalization

Normalization	CSP1	CSP2	CSP3	CSP4	CSP5	CSP6	CSP7
CSP1	0.09803	0.10408	0.05164	0.24641	0.13045	0.07384	0.06249
CSP2	0.16339	0.17347	0.15494	0.16156	0.17389	0.03989	0.18748
CSP3	0.18854	0.11121	0.09933	0.04928	0.11147	0.14202	0.12019
CSP4	0.06535	0.17639	0.33109	0.16427	0.17681	0.22526	0.19063
CSP5	0.16339	0.21689	0.19373	0.20199	0.21741	0.27698	0.23441
CSP6	0.01059	0.03469	0.00558	0.00582	0.00626	0.00798	0.00675
CSP7	0.31071	0.18326	0.16369	0.17067	0.1837	0.23403	0.19806

Priority vectors:

Table 2.37 : "No. of Pro" according priority vector

Priority vector	
CSP1	0.10956
CSP2	0.15066
CSP3	0.11743
CSP4	0.18997
CSP5	0.21497
CSP6	0.0111
CSP7	0.2063

Maximum Eigen value vector:

Table 2.38 : "No. of Pro" according Maximum Eigen value vector

Maximum Eigen value vector
0.842752249
1.125989634
0.91466203
1.494344724
1.677993906
0.079618446
1.610763117

The elements of the vector:

Table 2.39 : "No. of Pro" according the elements of the vector

The elements of the vector
7.691898746
7.473714047
7.788796712
7.866121036
7.805647363
7.174833556
7.807775814

The alternative priorities according the No. of Processors:

Table 2.40 : "No. of Pro" according alternatives priority

λ	7.658398182
CI	0.10973303
RI	1.32
CR	0.083131084

For RAM criterion:

The following values got by comparing the importance for each alternative due other alternative according to RAM in the original matrix:

Table 2.41 :"RAM" according alternatives comparing

RAM	CSP1	CSP2	CSP3	CSP4	CSP5	CSP6	CSP7
CSP1	1	1	1.61111	1.61111	1.61111	7	1.16
CSP2	1	1	1.61111	1.61111	1.61111	9	1.16
CSP3	0.62069	0.62069	1	1	1	4	0.72
CSP4	0.62069	0.62069	1	1	1	9	0.72
CSP5	0.62069	0.62069	1	1	1	9	0.72
CSP6	0.14286	0.11111	0.25	0.11111	0.11111	1	0.8
CSP7	0.86207	0.86207	1.38889	1.38889	1.38889	1.25	1

By normalizing the previous table we got:

Table 2.42 : "RAM" according alternatives comparing normalization

Normalization	CSP1	CSP2	CSP3	CSP4	CSP5	CSP6	CSP7
CSP1	0.20547	0.20681	0.20495	0.20863	0.20863	0.17391	0.18471
CSP2	0.20547	0.20681	0.20495	0.20863	0.20863	0.2236	0.18471
CSP3	0.12753	0.12837	0.12721	0.1295	0.1295	0.09938	0.11465
CSP4	0.12753	0.12837	0.12721	0.1295	0.1295	0.2236	0.11465
CSP5	0.12753	0.12837	0.12721	0.1295	0.1295	0.2236	0.11465
CSP6	0.02935	0.02298	0.0318	0.01439	0.01439	0.02484	0.12739
CSP7	0.17713	0.17829	0.17668	0.17986	0.17986	0.03106	0.15924

Priority vectors:

Table 2.43 : "RAM" according priority vector

Priority vector	
CSP1	0.19902
CSP2	0.20612
CSP3	0.1223
CSP4	0.14005
CSP5	0.14005
CSP6	0.03788
CSP7	0.15459

Maximum Eigen value vector:

Table 2-44 "RAM" according Maximum Eigen value vector

Maximum Eigen value vector
1.4979137
1.573669122
0.916678258
1.106066814
1.106066814
0.274576861
1.110079657

The elements of the vector:

Table 2-45 "RAM" according The elements of the vector

The elements of the vector
7.526557388
7.634886006
7.495080958
7.897644672
7.897644672
7.24903517
7.181023026

The alternative priorities according the RAM:

Table 2.46 : "RAM" according alternatives priority

ƛ	7.554553127
CI	0.092425521
RI	1.32
CR	0.070019334

For Easability criterion:

The following values got by comparing the importance for each alternative due other alternative according to Easability in the original matrix:

Table 2.47 :"Easability" according alternatives comparing

Easability	CSP1	CSP2	CSP3	CSP4	CSP5	CSP6	CSP7
CSP1	1	0.8	1	1	1	0.8	1
CSP2	1.25	1	1	1	1	1	1.2
CSP3	1	1	1	1	1	1	1
CSP4	1	1	1	1	1	1	1.2
CSP5	1	1	1	1	1	1	1
CSP6	1.25	1	1	1	1	1	1.2
CSP7	1	0.83333	1	0.83333	1	0.83333	1

By normalizing the previous table we got:

Table 2.48 : "Easability" according alternatives comparing normalization

Normalization	CSP1	CSP2	CSP3	CSP4	CSP5	CSP6	CSP7
CSP1	0.13333	0.1206	0.14286	0.14634	0.14286	0.1206	0.13158
CSP2	0.16667	0.15075	0.14286	0.14634	0.14286	0.15075	0.15789
CSP3	0.13333	0.15075	0.14286	0.14634	0.14286	0.15075	0.13158
CSP4	0.13333	0.15075	0.14286	0.14634	0.14286	0.15075	0.15789
CSP5	0.13333	0.15075	0.14286	0.14634	0.14286	0.15075	0.13158
CSP6	0.16667	0.15075	0.14286	0.14634	0.14286	0.15075	0.15789
CSP7	0.13333	0.12563	0.14286	0.12195	0.14286	0.12563	0.13158

Priority vectors:

Table 2.49 :"Easability" according priority vector

Priority vector	
CSP1	0.13402
CSP2	0.15116
CSP3	0.14264
CSP4	0.1464
CSP5	0.14264
CSP6	0.15116
CSP7	0.13198

Maximum Eigen value vector:

Table 2.50 :"Easability" according Maximum Eigen value vector

Maximum Eigen value vector
0.939535732
1.059901475
1
1.026395259
1
1.059901475
0.925213316

The elements of the vector:

Table 2.51 :"Easability" according The elements of the vector

The elements of the vector
7.010159846
7.011754282
7.010687319
7.010955708
7.010687319
7.011754282
7.010450729

The alternative priorities according the Easability:

Table 2.52 :"Easability" according alternatives priority

ƛ	7.010921355
CI	0.001820226
RI	1.32
CR	0.001378959

For Flexibility criterion:

The following values got by comparing the importance for each alternative due other alternative according to Flexibility in the original matrix:

Table 2.53 :"Flexibility" according alternatives comparing

Flexibility	CSP1	CSP2	CSP3	CSP4	CSP5	CSP6	CSP7
CSP1	1	0.9	0.9	0.9	0.9	1.1	1.1
CSP2	1.11111	1	1	1	1	1.1	1.1
CSP3	1.11111	1	1	1	1	1.1	1.1
CSP4	1.11111	1	1	1	1	1.1	1.1
CSP5	1.11111	1	1	1	1	1.2	1.2
CSP6	0.90909	0.90909	0.90909	0.90909	0.83333	1	1.05
CSP7	0.90909	0.90909	0.90909	0.90909	0.83333	0.95238	1

By normalizing the previous table we got:

Table 2.54 :"Flexibility" according alternatives comparing normalization

Normalization	CSP1	CSP2	CSP3	CSP4	CSP5	CSP6	CSP7
CSP1	0.13769	0.13396	0.13396	0.13396	0.13706	0.14565	0.14379
CSP2	0.15299	0.14885	0.14885	0.14885	0.15228	0.14565	0.14379
CSP3	0.15299	0.14885	0.14885	0.14885	0.15228	0.14565	0.14379
CSP4	0.15299	0.14885	0.14885	0.14885	0.15228	0.14565	0.14379
CSP5	0.15299	0.14885	0.14885	0.14885	0.15228	0.15889	0.15686
CSP6	0.12517	0.13532	0.13532	0.13532	0.1269	0.13241	0.13725
CSP7	0.12517	0.13532	0.13532	0.13532	0.1269	0.1261	0.13072

Priority vectors:

Table 2.55 :"Flexibility" according priority vector

Priority vector	
CSP1	0.13801
CSP2	0.14875
CSP3	0.14875
CSP4	0.14875
CSP5	0.15251
CSP6	0.13253
CSP7	0.13069

Maximum Eigen value vector:

Table 2-56 "Flexibility" according Maximum Eigen value vector

Maximum Eigen value vector
0.966445415
1.041656755
1.041656755
1.041656755
1.067978879
0.928000919
0.915155399

The elements of the vector:

Table 2.57 : "Flexibility" according The elements of the vector

The elements of the vector
7.002634601
7.002638981
7.002638981
7.002638981
7.002635378
7.00230928
7.002308018

The alternative priorities according the Flexibility:

Table 2.58 :"Flexibility" according alternatives priority

ƛ	7.00254346
CI	0.00042391
RI	1.32
CR	0.000321144

In the previous steps we ensured that the CR for all the criteria and alternatives are <0.1, so we can now rank the alternatives as the following table shows:

The result column came from the sum of multiplying the criteria properties values with the normalized original matrix

Table 2.59 : AHP ranking result

	Result	Rank
CSP1	0.170140603	2
CSP2	0.195210434	1
CSP3	0.10873559	6
CSP4	0.145243654	3
CSP5	0.14151022	5
CSP6	0.094141695	7
CSP7	0.145017803	4

2.2.2 Solution of Problem with ANP Method

Super Decisions V2 software was used to construct the relationships of internal networks among the criteria and alternatives, internal dependencies and external dependencies, to make binary comparisons and to calculate weights.

Figure shows the network structure defined between the criteria and alternatives set out for the problem of selecting Cloud Service Providers.

An internal dependency between Easability and Flexibility within the usability set is defined.

An internal dependency is defined between the Virtual machine cost and the Transfer cost within the cost set.

An internal dependency is defined between the storage area within the agility cluster and the number of virtual machines.

An internal dependency between the number of processors and RAM (GB) in the performance set is defined.

There is a relationship between each criterion and all other criteria in other clusters.

Note: in the appendix A more details about ANP implementation

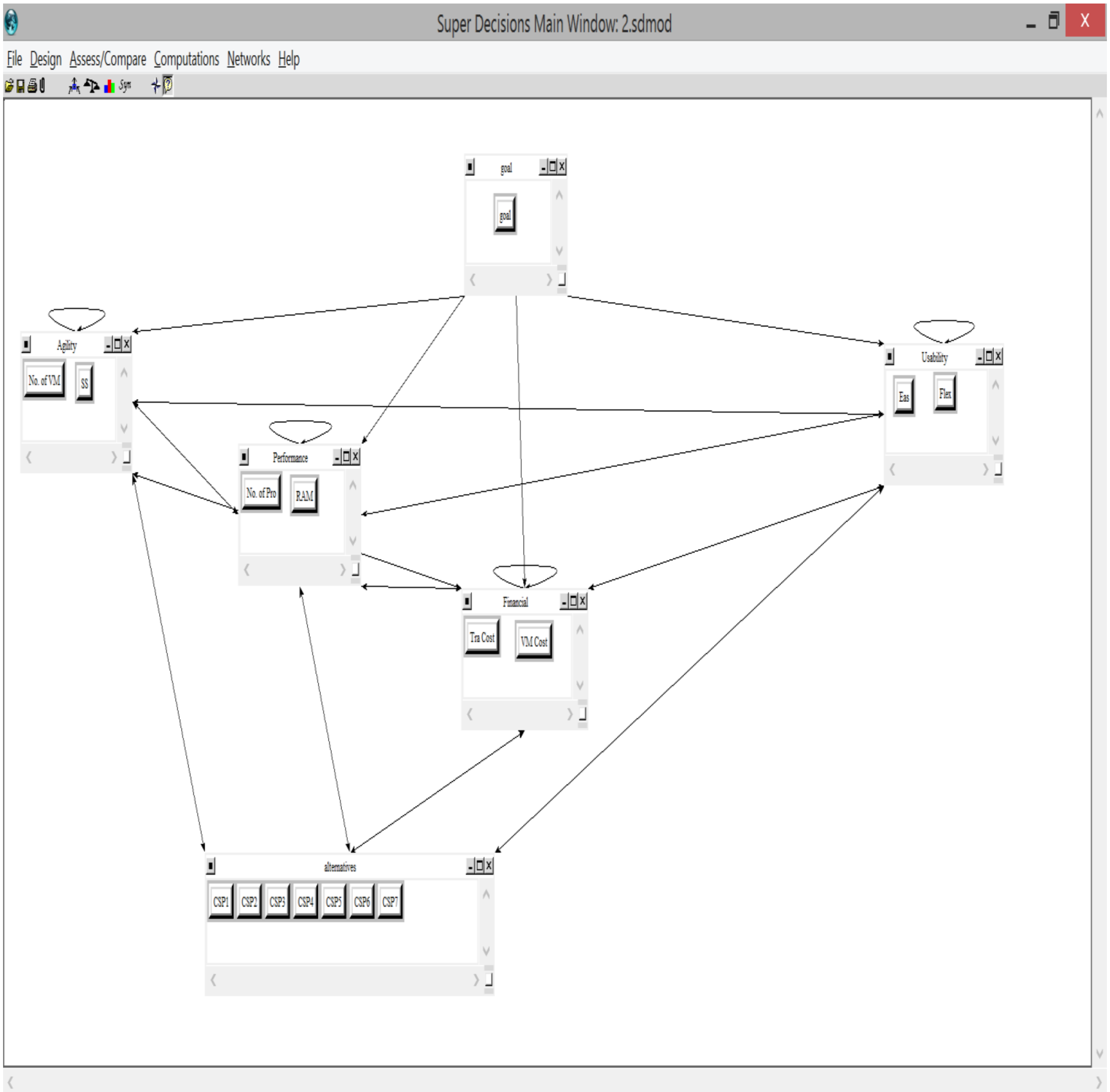


Figure 2.1 : Network structure defined among the criteria and alternatives identified for the cloud service provider selection problem

Table shows the output of the super reconciliation program screen, where the solution priorities of the alternatives identified for the cloud service provider selection problem are based on the ANP method.

Table 2.60 : Alternatives priorities

Name	Normalized By Cluster
CSP1	0.15732
CSP2	0.23025
CSP3	0.09349
CSP4	0.15327
CSP5	0.1797
CSP6	0.07492
CSP7	0.11105

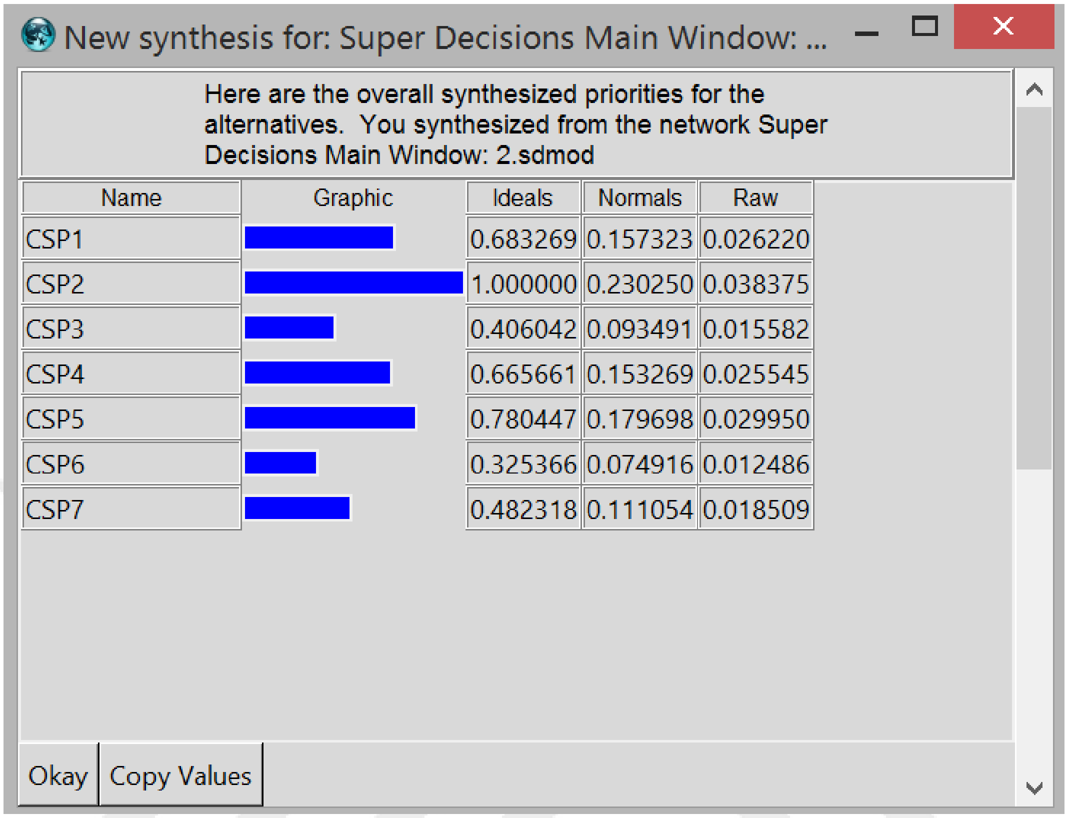


Figure 2.2 : Super Decision Screen Display of Priorities of Alternatives

Table 66 shows the result of the application of the ANP method, where the CSPs are ranked according to their ability to achieve the goal, CSP2 takes the first order.

Table 2.61: ANP ranking result

Graphic	Alternatives	Total	Normal	Ideal	Ranking
	CSP1	0.0262	0.1573	0.6833	3
	CSP2	0.0384	0.2303	1.0000	1
	CSP3	0.0156	0.0935	0.4060	6
	CSP4	0.0255	0.1533	0.6657	4
	CSP5	0.0299	0.1797	0.7804	2
	CSP6	0.0125	0.0749	0.3254	7
	CSP7	0.0185	0.1111	0.4823	5

2.2.3 Solution of Problem with TOPSIS Method

The normalized decision matrix by using the following formula:

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}} \tag{2.4}$$

for i=1,……..,m; and j=1,…….,n;

Table 2.62:Normalized original matrix

	C1	C2	C3	C4	C5	C6	C7	C8
CSP1	0.4	0.61532	0.4	0.176415	0.145656934	0.478116	0.355282	0.368935
CSP2	0.6	0.574709	0.6	0.705662	0.436997033	0.478116	0.399692	0.390637
CSP3	0.1	0.134755	0.1	0.11761	0.280139755	0.296762	0.377487	0.390637
CSP4	0.3	0.369192	0.3	0.470441	0.444341521	0.296762	0.386369	0.390637
CSP5	0.6	0.179673	0.6	0.470441	0.546377443	0.296762	0.377487	0.390637
CSP6	0.1	0.098451	0.1	0.024992	0.015738188	0.329735	0.399692	0.364594
CSP7	0.1	0.30766	0.1	0.11761	0.461653528	0.412169	0.3464	0.347233

The weight for each criterion calculated:

Table 2.63 : Criterion weight

weights	0.024621	0.190068	0.024595	0.015864	0.132702626	0.343519	0.13483	0.13379

The weighted normalized matrix calculated:

Table 2.64 : Weighted normalized matrix

	C1	C2	C3	C4	C5	C6	C7	C8
CSP1	0.009848	0.116953	0.009838	0.002799	0.019329058	0.164242	0.04790	0.04936
CSP2	0.014773	0.109234	0.014757	0.011194	0.057990654	0.164242	0.05389	0.05226
CSP3	0.002462	0.025613	0.002459	0.001866	0.037175281	0.101943	0.0509	0.05226
CSP4	0.007386	0.070172	0.007378	0.007463	0.058965287	0.101943	0.05209	0.05226
CSP5	0.014773	0.03415	0.014757	0.007463	0.072505721	0.101943	0.0509	0.05226
CSP6	0.002462	0.018712	0.002459	0.000396	0.002088499	0.11327	0.05389	0.04878
CSP7	0.002462	0.058476	0.002459	0.001866	0.061262635	0.141588	0.04670	0.04645

The positive ideal (A+) and negative ideal (A-) values calculated:

Table 2.65 : Positive ideal (A+) and negative ideal (A-) values

ideal	**0.01477**	**0.11695**	**0.01475**	**0.01119**	**0.07250572**	**0.16424**	**0.05389**	**0.05226**
worst	0.002462	0.018712	0.002459	0.00039	0.00208849	0.10194	0.04670	0.04645

Calculating the separation from the positive and the separation from the negative ideal alternative.

Table 2.66 : Separation from positive ideal table

	C1	C2	C3	C4	C5	C6	C7	C8
CSP1	0.004924	0	0.004919	0.008396	0.053176664	0	0.005988	0.002904
CSP2	0	0.007719	0	0	0.014515068	0	0	0
CSP3	0.01231	0.09134	0.012297	0.009329	0.03533044	0.062299	0.002994	0
CSP4	0.007386	0.046781	0.007378	0.003731	0.013540435	0.062299	0.001796	0
CSP5	0	0.082803	0	0.003731	0	0.062299	0.002994	0
CSP6	0.01231	0.09824	0.012297	0.010798	0.070417222	0.050972	0	0.003484
CSP7	0.01231	0.058476	0.012297	0.009329	0.011243086	0.022654	0.007186	0.005807

Table 2.67 : Separation from negative ideal table

	C1	C2	C3	C4	C5	C6	C7	C8
CSP1	0.007386	0.09824	0.007378	0.002402	0.017240559	0.062299	0.001198	0.002904
CSP2	0.01231	0.090521	0.012297	0.010798	0.055902155	0.062299	0.007186	0.005807
CSP3	0	0.0069	0	0.001469	0.035086782	0	0.004192	0.005807
CSP4	0.004924	0.051459	0.004919	0.007066	0.056876788	0	0.005389	0.005807
CSP5	0.01231	0.015438	0.012297	0.007066	0.070417222	0	0.004192	0.005807
CSP6	0	0	0	0	0	0.011327	0.007186	0.002323
CSP7	0	0.039764	0	0.001469	0.059174136	0.039645	0	0

Calculation of separation measures:

Table 2.68 :Separation measures

	di+	di-
CSP1	0.05469	0.118128
CSP2	0.01644	0.12532
CSP3	0.117776	0.036499
CSP4	0.079869	0.077744
CSP5	0.103732	0.074839
CSP6	0.132813	0.013614
CSP7	0.067337	0.081588

The closeness coefficients are calculated:

Table 2.69 : Ideal closeness coefficients and TOPSIS ranking

	di+	di-	ci	Result - rank
CSP1	0.05469	0.118128	0.68354	2
CSP2	0.01644	0.12532	0.88403	1
CSP3	0.117776	0.036499	0.236582	6
CSP4	0.079869	0.077744	0.493259	4
CSP5	0.103732	0.074839	0.419101	5
CSP6	0.132813	0.013614	0.092973	7
CSP7	0.067337	0.081588	0.547847	3

2.2.4 Solving the problem with ELECTRE method

İn the following the normalized original matrix:

Table 2.70 : Normalized original matrix

	C1	C2	C3	C4	C5	C6	C7	C8
CSP1	0.4	0.61532	0.4	0.176415	0.145656934	0.478116	0.355282	0.368935
CSP2	0.6	0.574709	0.6	0.705662	0.436997033	0.478116	0.399692	0.390637
CSP3	0.1	0.134755	0.1	0.11761	0.280139755	0.296762	0.377487	0.390637
CSP4	0.3	0.369192	0.3	0.470441	0.444341521	0.296762	0.386369	0.390637
CSP5	0.6	0.179673	0.6	0.470441	0.546377443	0.296762	0.377487	0.390637
CSP6	0.1	0.098451	0.1	0.024992	0.015738188	0.329735	0.399692	0.364594
CSP7	0.1	0.30766	0.1	0.11761	0.461653528	0.412169	0.3464	0.347233

The weights of each criteria are then multiplied by the normalized matrix (R matrix) as follows:

$$V_{ij} = R_x W = \begin{bmatrix} r_{11}.w_1 & r_{12}.w_2 & \dots & r_{1n}.w_n \\ r_{21}.w_1 & r_{22}.w_2 & \dots & r_{2n}.w_n \\ . & . & . & . \\ . & . & . & . \\ . & . & . & . \\ r_{m1}.w_1 & r_{m2}.w_2 & . & r_{mn}.w_n \end{bmatrix} \quad (2.5)$$

We get the V matrix:

Table 2.71 : Weighted normalized matrix

	C1	C2	C3	C4	C5	C6	C7	C8
CSP1	0.024441	0.145916	0.089814	0.038786	0.013772	0.027851	0.010959	0.0272
CSP2	0.036662	0.136286	0.13472	0.155143	0.041317	0.027851	0.012329	0.0288
CSP3	0.00611	0.031956	0.022453	0.025857	0.026487	0.017287	0.011644	0.0288
CSP4	0.018331	0.08755	0.06736	0.103429	0.042012	0.017287	0.011918	0.0288
CSP5	0.036662	0.042608	0.13472	0.103429	0.051659	0.017287	0.011644	0.0288
CSP6	0.00611	0.023347	0.022453	0.005495	0.001488	0.019207	0.012329	0.02688
CSP7	0.00611	0.072958	0.022453	0.025857	0.043649	0.024009	0.010685	0.0256

By applying the next formula on the V matrix:

$$C_{ab=} = \{j | x_{aj} \geq x_{bj} |\}$$

We get:

C12 = {2,6}
C21 = {1,3,4,5,6,7,8}
C31 = {5,7,8}
C41 = {4,5,7,8}
C13 = {1,2,3,4,6}
C23 = {1,2,3,4,5,6,7,8}
C32 = {8}
C42 = {5,8}
C14 = {1,2,3,6}
C24 = {1,2,3,4,6,7,8}
C34 = {6,8}
C43 = {1,2,3,4,5,6,7,8}
C15 = {2,6}
C25 = {1,2,3,4,6,7,8}
C35 = {6,7,8}

C51 = {1,3,4,5,7,8}
C61 = {7}
C71 = {5}
C52 = {1,3,5,8}
C62 = {1,7}
C72 = {5}
C53 = {1,2,3,4,5,6,7,8}
C63 = {1,3,6,7}
C73 = {1,2,3,4,5,6}
C54 = {1,3,4,5,6,8}
C64 = {6,7}
C74 = {5,6}
C56 = {1,2,3,4,5,8}
C65 = {7}
C75 = {2,6}

C45 = {2,4,6,7,8}
C16 = {1,2,3,4,5,6,8}
C26 = {1,2,3,4,5,6,7,8}
C36 = {1,2,3,4,5,8}
C46 = {1,2,3,4,5,8}
C17 = {1,2,3,4,6,7,8}
C27 = {1,2,3,4,6,7,8}
C37 = {1,3,4,7,8}
C47 = {1,2,3,4,7,8}
C57 = {1,3,4,5,7,8}
C67 = {1,3,7,8}
C76 = {1,2,3,4,5,6}

And by applying the next formula on the V matrix:

$$D_{ab} = \{j|x_{aj} \geq x_{bj}|\} = J - C_{ab}$$

We get:

D12 = {1,3,4,5,7,8}
D21 = {2}
D31 = {1,2,3,4,6}
D41 = {1,2,3,6}
D13 = {5,7,8}
D23 = { }
D32 = {1,2,3,4,5,6,7}
D42 = {1,2,3,4,6,7}
D14 = {4,5,7,8}
D24 = {5}
D34 = {1,2,3,4,5,7}
D43 = { }
D15 = {1,3,4,5,7,8}
D25 = {5}
D35 = {1,2,3,4,5}
D45 = {1,3,5}
D16 = {7}
D26 = { }
D36 = {6,7}
D46 = {6,7}
D17 = {5}
D27 = {5}
D37 = {2,5,6}
D47 = {5,6}
D51 = {2,6}
D61 = {1,2,3,4,5,6,8}
D71 = {1,2,3,4,6,7,8}
D52 = {2,4,6,7}
D62 = {2,3,4,5,6,8}
D72 = {1,2,3,4,6,7,8}
D53 = { }
D63 = {2,4,5,8}
D73 = {7,8}
D54 = {2,7}
D64 = {1,2,3,4,5,8}
D74 = {1,2,3,4,7,8}
D56 = {6,7}
D65 = {1,2,3,4,5,6,8}
D75 = {1,3,4,5,7,8}
D57 = {2,6}
D67 = {2,4,5,6}
D76 = {7,8}

Next, we use the previous result to construct the matrix C; the elements are calculated as follows:

$$C_{ab} = \sum_{j \in C_{ab}} w_j \tag{2.6}$$

Table 2.72 : C Matrix

-	0.29539	0.800881	0.581027	0.581027	0.969154	0.905452
0.762861	-	1	0.905452	0.905452	1	0.905452
0.199119	0.073725	-	0.131976	0.162822	0.910903	0.610062
0.418973	0.168273	1	-	0.619815	0.910903	0.847201
0.70461	0.45391	1	0.732016	-	0.390207	0.70461
0.030846	0.030846	0.374733	0.089097	0.089097	-	0.390207
0.094548	0.094548	0.895429	0.152799	0.29539	0.895429	-

And then we form the matrix D, which calculates these elements as follows:

$$d_{ab} = \frac{\max_{j \in D_{ab}} \left| V_{aj} - V_{bj} \right|}{\max_{j \in J, m, n \in I} \left| V_{mj} - V_{nj} \right|} \tag{2.7}$$

Table 2.73 :D matrix

-	**0.116357**	**0.012715**	**0.064643**	**0.064643**	**0.00137**	**0.06736**
0.00963	-	0	0.000694	0.010342	0	0.112267
0.113961	0.129286	-	0.077571	0.112267	0.001921	0.041002
0.058366	0.06736	0	-	0.06736	0.001921	0.006723
0.103309	0.093678	0	0.044942	-	0.001921	0.030351
0.12257	0.149648	0.024999	0.097934	0.112267	-	0.049612
0.072958	0.129286	0.0032	0.077571	0.112267	0.001644	-

And next, we need to calculate $\bar{c}$ from the following formula:

$$\bar{c} = \sum_{a=1}^{m} \sum_{b}^{m} c(a,b) | m(m-1) \qquad (2.8)$$

Which equal to (0.416416), so we compare each element of C matrix with this value to get E matrix which its elements calculated by the following formulation:

e(a,b) = 0; if (a,b) < $\bar{c}$, e(a,b) = 1; if (a,b) $>=$ $\bar{c}$

So we get E matrix:

Table 2.74 : E matrix

0	**0**	**1**	**1**	**0**	**1**	**1**
1	0	1	1	1	1	1
0	0	0	0	0	1	1
1	0	1	0	1	1	1
1	1	1	1	0	1	1
0	0	0	0	0	0	0
0	0	1	0	0	1	0

And then -in the same way-, we form the matrix F from matrix D:

Table 2.75 : F matrix

0	**1**	**0**	**1**	**1**	**1**	**1**
0	0	0	0	0	0	1
1	1	0	1	1	0	1
1	1	0	0	1	0	0
1	1	0	1	0	1	0
1	0	1	1	1	0	0
1	1	0	1	1	0	0

And in the last step we use the C and D matrices to derive the final result according to these two formulas:

$$C_k = \sum_{\substack{l=1 \\ l\neq k}}^{m} C_{kl} - \sum_{\substack{i=1 \\ l\neq k}}^{m} C_{lk} \qquad d_k = \sum_{\substack{l=1 \\ l\neq k}}^{m} dC_{kl} - \sum_{\substack{l=1 \\ l\neq k}}^{m} d_{lk} \tag{2.9}$$

Table 2.76 : Ck and Dk values

C1	1.636337	D1	-0.3251
C2	4.362525	D2	-4.09522
C3	-2.98244	D3	3.740725
C4	1.372799	D4	-1.6951
C5	2.138084	D5	-0.79859
C6	-4.59247	D6	2.070603
C7	-1.93484	D7	1.102677

The final result is shown in the following table:

Table 2.77 :ELECTRE ranking result

	Top Value	Top Ranking	Lowest Value	Bottom Value Order
CSP1	1.636337	3	-0.3251	4
CSP2	4.362525	1	-4.09522	1
CSP3	-2.98244	6	3.740725	7
CSP4	1.372799	4	-1.6951	2
CSP5	2.138084	2	-0.79859	3
CSP6	-4.59247	7	2.070603	6
CSP7	-1.93484	5	1.102677	5

2.2.5 Solution of Problem with VIKOR Method

For each criterion $f^+{}_i$ and $f^-{}_i$ values calculated:

Table 2.78 : f+i and f- i' values

Criteria	$f^+{}_i$	$f^-{}_i$
No. of Vm	12	2
SS	1	0.16
No. of Pro.	12	2
RAM	48	1.7
VM cost	2.083	0.06
Tra. Cost	0.29	0.18
Ease.	0.9	0.78
Flex.	0.9	0.8

For each alternative S_j and R_j values calculated:

$$S_j = \sum_{k=1}^{n} w_i \left(f_i^+ - f_{ij}\right)/(f_i^+ - f_i^-) \tag{2.10}$$

$$R_j = max\left[w_i\left(f_i^+ - f_{ij}\right)/(f_i^+ - f_i^-)\right] \tag{2.11}$$

Table 2.79 : $\mathbf{S_j}$ and $\mathbf{R_j}$ values

Alternatives	$\boldsymbol{S_j}$	$\boldsymbol{R_j}$
CSP1	0.311495	0.112366
CSP2	0.042288	0.027354
CSP3	0.705922	0.343519
CSP4	0.528266	0.343519
CSP5	0.565384	0.343519
CSP6	0.749186	0.281061
CSP7	0.590791	0.134839

then Qj values by using the following formula calculated:

$$Q_J = \frac{v\left(S_j - S^+\right)}{(S^- - S^+)} + \frac{(1-v)\left(R_j - R^+\right)}{(R^- - R^+)} \tag{2.12}$$

Table 2.80 : Q_j ' values

Alternatives	Q
CSP1	0.324857
CSP2	0
CSP3	0.969399
CSP4	0.84374
CSP5	0.869994
CSP6	0.901226
CSP7	0.557948

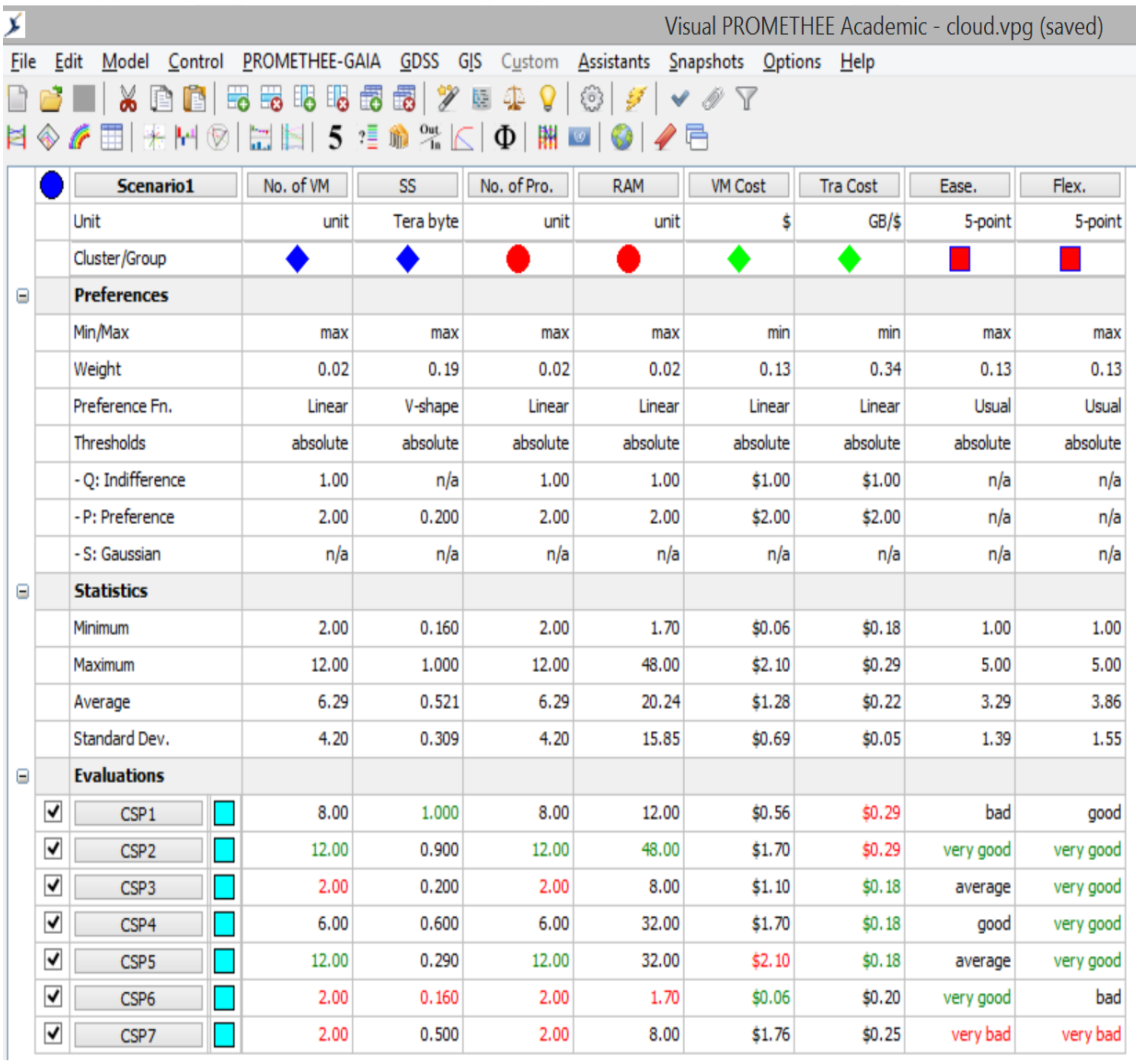
After that we rank the alternatives:

Table 2.81 :VIKOR ranking result

Alternatives	Q_J	Ranking
CSP1	0.324857	2
CSP2	0	1
CSP3	0.969399	7
CSP4	0.84374	4
CSP5	0.869994	5
CSP6	0.901226	6
CSP7	0.557948	3

2.2.6 Solution of Problem with PROMETHEE Method

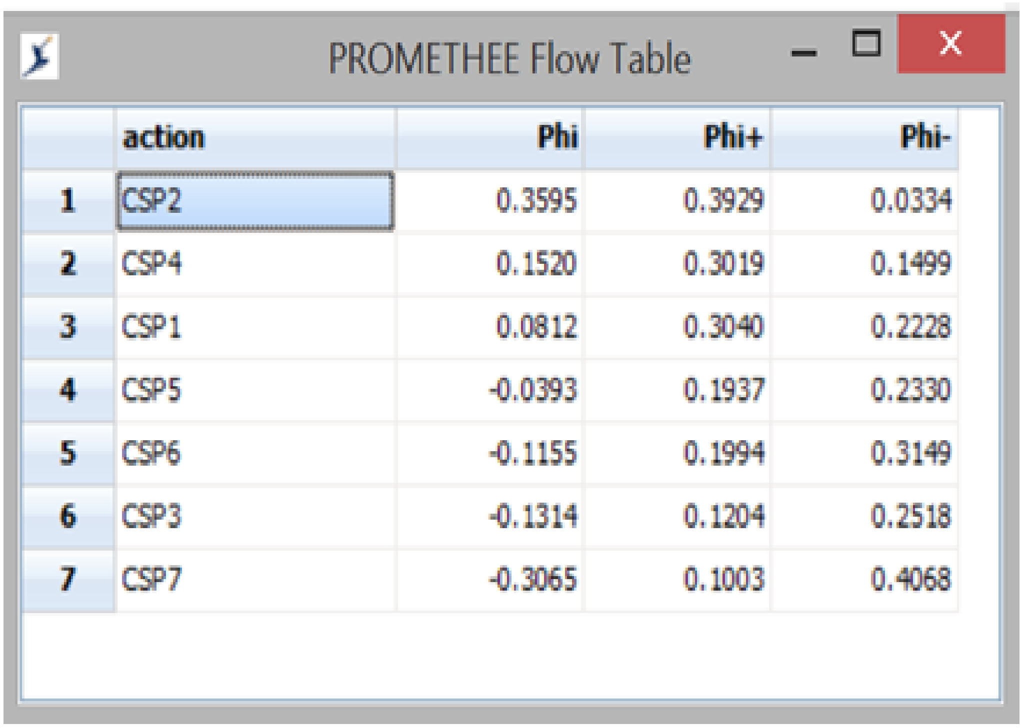
To build the solution the "Visual PROMETHEE Academic" program used, the program interface will be as seen in the following figure. Eight clumns added representing each creterion, in the cluster line we combine each two crteria togethers which represented by the same shape; in the Min/Max line we select min if we want to minimize thie crterion or max if we want to maximize i; the weight extracted from the weight matrix which used previously; the appropriate preference function selected for each crterion in the preference function line; thresholde selected according to the preference function selected ; the other statics measurce extracted from the original matrix.



Scenario1	No. of VM	SS	No. of Pro.	RAM	VM Cost	Tra Cost	Ease.	Flex.
Unit	unit	Tera byte	unit	unit	$	GB/$	5-point	5-point
Cluster/Group	◆	◆	●	●	◆	◆	■	■
Preferences								
Min/Max	max	max	max	max	min	min	max	max
Weight	0.02	0.19	0.02	0.02	0.13	0.34	0.13	0.13
Preference Fn.	Linear	V-shape	Linear	Linear	Linear	Linear	Usual	Usual
Thresholds	absolute	absolute	absolute	absolute	absolute	absolute	absolute	absolute
- Q: Indifference	1.00	n/a	1.00	1.00	$1.00	$1.00	n/a	n/a
- P: Preference	2.00	0.200	2.00	2.00	$2.00	$2.00	n/a	n/a
- S: Gaussian	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Statistics								
Minimum	2.00	0.160	2.00	1.70	$0.06	$0.18	1.00	1.00
Maximum	12.00	1.000	12.00	48.00	$2.10	$0.29	5.00	5.00
Average	6.29	0.521	6.29	20.24	$1.28	$0.22	3.29	3.86
Standard Dev.	4.20	0.309	4.20	15.85	$0.69	$0.05	1.39	1.55
Evaluations								
CSP1	8.00	1.000	8.00	12.00	$0.56	$0.29	bad	good
CSP2	12.00	0.900	12.00	48.00	$1.70	$0.29	very good	very good
CSP3	2.00	0.200	2.00	8.00	$1.10	$0.18	average	very good
CSP4	6.00	0.600	6.00	32.00	$1.70	$0.18	good	very good
CSP5	12.00	0.290	12.00	32.00	$2.10	$0.18	average	very good
CSP6	2.00	0.160	2.00	1.70	$0.06	$0.20	very good	bad
CSP7	2.00	0.500	2.00	8.00	$1.76	$0.25	very bad	very bad

Figure 2.3 : Visual PROMETHEE Academic" program interface

In the following the alternatives ranking result:



PROMETHEE Flow Table

	action	Phi	Phi+	Phi-
1	CSP2	0.3595	0.3929	0.0334
2	CSP4	0.1520	0.3019	0.1499
3	CSP1	0.0812	0.3040	0.2228
4	CSP5	-0.0393	0.1937	0.2330
5	CSP6	-0.1155	0.1994	0.3149
6	CSP3	-0.1314	0.1204	0.2518
7	CSP7	-0.3065	0.1003	0.4068

Figure 2.4 : PROMETHEE ranking result

2.3 COMPARING RESULTS:

Due to the previous implementation for the six methods to rank the CSPs to choose the most appropriate provider to our case study, a different estimation has been got for the different CSPs, for that there is a need to compare the methods implementation' results to choose the rank which most of the methods agreed on it. In fact there are no ready method or tool to do that, for that we build our algorithm to implement the comparison, this algorithm has programmed using C programing language (note: the code is provided in the appendix B), the algorithms consists from many steps as following:

1. Arranging the methods ranking result in a two dimension matrix the methods ranking in the columns and the CSPs in the rows and in the cells the rank of each CSPs by each method. As seen in the following table:

Table 2.82 : Methods ranking results

CSPs names	Order By					
	ANP	AHP	ELECTRE	PROMETHEE	TOPSIS	VIKOR
CSP1	3	2	3	3	2	2
CSP2	1	1	1	1	1	1
CSP3	6	6	6	6	6	7
CSP4	4	3	4	2	4	4
CSP5	2	5	2	4	5	5
CSP6	7	7	7	5	7	6
CSP7	5	4	5	7	3	3

2. From the previous matrix extracting a new two dimensions matrix, in its rows the CSPs, in the columns ranking from 1 to 7 and in the cells the total number of times each provider is repeated. As seen in the following table:

Table 2.83 : Total number of times each provider is repeated

CSPs names	**1**	**2**	**3**	**4**	**5**	**6**	**7**
CSP1	0	3	3	0	0	0	0
CSP2	6	0	0	0	0	0	0
CSP3	0	0	0	0	0	5	1
CSP4	0	1	1	4	0	0	0
CSP5	0	2	0	1	3	0	0
CSP6	0	0	0	0	1	1	4
CSP7	0	0	2	1	2	0	1

3. Normalizing the previous matrix by dividing the total number of times each provider is repeated/ the number of methods* 100. As seen in the following table:

Table 2.84 : Normalizing the total number of times each provider repeated

CSPs names	**1**	**2**	**3**	**4**	**5**	**6**	**7**
CSP1	0.00	50.00	50.00	0.00	0.00	0.00	0.00
CSP2	100.00	0.00	0.00	0.00	0.00	0.00	0.00
CSP3	0.00	0.00	0.00	0.00	0.00	83.33	16.67
CSP4	0.00	16.67	16.67	66.67	0.00	0.00	0.00
CSP5	0.00	33.33	0.00	16.67	50.00	0.00	0.00
CSP6	0.00	0.00	0.00	0.00	16.67	16.67	66.67
CSP7	0.00	0.00	33.33	16.67	33.33	0.00	16.67

4. Ignore the provider who has the max percentage less than 50 % (where that means there are no agreement at least between three methods about the ranking of this provider).

for example in the previous table we ignore the CSP7, as seen in the following table 2-85:

Table 2.86 : Normalizing table without percentages less than 50%

CSPs names	1	2	3	4	5	6	7
CSP1	0.00	50.00	50.00	0.00	0.00	0.00	0.00
CSP2	100.00	0.00	0.00	0.00	0.00	0.00	0.00
CSP3	0.00	0.00	0.00	0.00	0.00	83.33	16.67
CSP4	0.00	16.67	16.67	66.67	0.00	0.00	0.00
CSP5	0.00	33.33	0.00	16.67	50.00	0.00	0.00
CSP6	0.00	0.00	0.00	0.00	16.67	16.67	66.67

5. From the previous matrix extract the ranking for each CSPs by the taking the higher percentage.

Table 2.87 : The CSPs ranking

CSPs names	MAX OF CSPs by times	RANK	MAX OF CSPs by percentage
CSP 2	6	1	100.00
CSP 1	3	2	50.00
CSP 1	3	3	50.00
CSP 4	4	4	66.67
CSP 5	3	5	50.00
CSP 3	5	6	83.33
CSP 6	4	7	66.67

Note: in the case that there are two rank for one CSPs, then the decision maker can decide

In the following the algorithms implementation in "C" programming languages (APPENDEX B), and its output for each step and the final result:

```
        CPSs  ||        ANP     AHP   ELECTRE  PROMETHEE  TOPSIS  VIKOR //
        CPS 1 ||        3       2       3       3       2       2
        CPS 2 ||        1       1       1       1       1       1
        CPS 3 ||        6       6       6       6       6       7
        CPS 4 ||        4       3       4       2       4       4
        CPS 5 ||        2       5       2       4       5       5
        CPS 6 ||        7       7       7       5       7       6
        CPS 7 ||        5       4       5       7       3       3
               // ******************** Output 1 Part 1 *********************************//
                Names of CPSs   ||       Structures Of CPSs (Arrangement)
        ========================||   1st || 2nd || 3rd || 4th || 5th || 6th || 7th ||
                CPS 1           ||    0  ||  3  ||  3  ||  0  ||  0  ||  0  ||  0  ||
                CPS 2           ||    6  ||  0  ||  0  ||  0  ||  0  ||  0  ||  0  ||
                CPS 3           ||    0  ||  0  ||  0  ||  0  ||  0  ||  5  ||  1  ||
                CPS 4           ||    0  ||  1  ||  1  ||  4  ||  0  ||  0  ||  0  ||
                CPS 5           ||    0  ||  2  ||  0  ||  1  ||  3  ||  0  ||  0  ||
                CPS 6           ||    0  ||  0  ||  0  ||  0  ||  1  ||  1  ||  4  ||
                CPS 7           ||    0  ||  0  ||  2  ||  1  ||  2  ||  0  ||  1  ||
               // ******************** Output 2 Part 1 *********************************//
        CPS 1 ||   0.00  50.00  50.00  0.00  0.00  0.00  0.00
        CPS 2 ||   100.00  0.00  0.00  0.00  0.00  0.00  0.00
        CPS 3 ||   0.00  0.00  0.00  0.00  0.00  83.33  16.67
        CPS 4 ||   0.00  16.67  16.67  66.67  0.00  0.00  0.00
        CPS 5 ||   0.00  33.33  0.00  16.67  50.00  0.00  0.00
        CPS 6 ||   0.00  0.00  0.00  0.00  16.67  16.67  66.67
        CPS 7 ||   0.00  0.00  33.33  16.67  33.33  0.00  16.67
       // ******************** Output 1 of 2 ********************************//

        CPS 1 ||   0.00  50.00  50.00  0.00  0.00  0.00  0.00
        CPS 2 ||   100.00  0.00  0.00  0.00  0.00  0.00  0.00
        CPS 3 ||   0.00  0.00  0.00  0.00  0.00  83.33  16.67
        CPS 4 ||   0.00  16.67  16.67  66.67  0.00  0.00  0.00
        CPS 5 ||   0.00  33.33  0.00  16.67  50.00  0.00  0.00
        CPS 6 ||   0.00  0.00  0.00  0.00  16.67  16.67  66.67

        Note:
               The CPS Number 7 is cancling

       // ******************** Output 2 Part 2********************************//
       || Name OF CPS || MAX OF ||  Rank  ||
       || ============================== ||
       ||  CPS   2    ||   6    ||   1    ||
       ||  CPS   1    ||   3    ||   2    ||
       ||  CPS   1    ||   3    ||   3    ||
       ||  CPS   4    ||   4    ||   4    ||
       ||  CPS   5    ||   3    ||   5    ||
       ||  CPS   3    ||   5    ||   6    ||
       ||  CPS   6    ||   4    ||   7    ||

--------------------------------
Process exited after 0.6286 seconds with return value 0
Press any key to continue . . .
```

Figure 2-5 Comparison algorithm implementation

2.4 CONCLUSION:

In this research, a company wants to select one from the exist CSPs in the market to use the Iaas services; there are a lot of CSPs in the market, in this study a comparison done between seven CSPs alternatives; they are differentiated according to eight criteria extracted from a previous study.

Within the scope of the study, a Cloud Service Provider selection problem is one of the MCDM problem; six MCDM methods used to discover the most appropriate CSP (HP, ANP, TOPSIS, ELECTRE, PROMETHEE and VICOR methods), all the methods have been explained from the theoretical side and implemented on our case using a different tools.

And a new algorithm has been invented to compare the ranking results for all the methods to extract the most agreeable CSP between all CSPs, and to be a first step to assess a general comparing algorithm for such problems. All the methods agreed on the second CSP (Rackspace) as the best provider, where it takes the first rank according to all methods. And the other CSPs are ranked according to their appropriate to our problem; which take off the ambiguity which facing the decision maker in the selecting process to a sufficient CSP which provide the appropriate and fulfill the company needs in the Iaas.

2.5 FUTURE WORK:

In this research, we shed the light on a very important problem facing the decision makers in the Cloud Service market, and we provide a solution to this problem; but with the wide in the cloud service market and entering a new CSPs, we suggest to add more providers to the study, and maybe doing more research about the criteria which can help to rank the CSPs according them.

Also the comparison algorithm which provided in this study is not the final version and can be developed to be a general algorithm to receipt more MCDM methods and to compare between them.

Also the research in the MCDM methods didn’t finish, all the time a new development on the methods appears and a new methods appear, for that in the future an enhancement methods can be tested or a totally new methods can be explained and implemented in our case study.

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4. APPENDIX A

SOLUTION OF PROBLEM WITH ANP METHOD

In the following the comparison matrix used in the ANP method implementation:

This matrix shows the important for each CSP comparing to all others, this matrix extracted from the original matrix

In the following unweight super matrix, in this matrix the importance for each criterion and CSPs compared according to the CSPs:

	CSP1	CSP2	CSP3	CSP4	CSP5	CSP6	CSP7
CSP1	0	0	0	0	0	0	0
CSP2	0	0	0	0	0	0	0
CSP3	0	0	0	0	0	0	0
CSP4	0	0	0	0	0	0	0
CSP5	0	0	0	0	0	0	0
CSP6	0	0	0	0	0	0	0
CSP7	0	0	0	0	0	0	0
cloud services	0	0	0	0	0	0	0
Ease.	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Flex.	0.5	0.5	0.5	0.5	0.5	0.5	0.5
VM Cost	0.66667	0.85714	0.85714	0.9	0.9	0.25	0.875
Tra Cost	0.33333	0.14286	0.14286	0.1	0.1	0.75	0.125
No. of Pros.	0.66667	0.1	0.2	0.14286	0.25	0.5	0.2
RAM	0.33333	0.9	0.8	0.85714	0.75	0.5	0.8
SS	0.11111	0.1	0.9	0.14286	0.5	0.5	0.2
No. of VM	0.88889	0.9	0.1	0.85714	0.5	0.5	0.8

in the following unweight super matrix 2 , in this matrix the importance for each criterion and CSPs compared according to the creterion:

	cloud servies	Ease.	Flex.	VM Cost	Tra Cost	No. of Pros.	RAM	SS	No. of VM
CSP1	0	0.14286	0.14286	0.05715	0.18852	0.22963	0.09638	0.26984	0.13068
CSP2	0	0.14286	0.14286	0.20283	0.18852	0.23807	0.34001	0.26141	0.2612
CSP3	0	0.14286	0.14286	0.14655	0.114	0.04503	0.05659	0.05946	0.04203
CSP4	0	0.14286	0.14286	0.18254	0.114	0.1431	0.21185	0.15096	0.1306
CSP5	0	0.14286	0.14286	0.20283	0.114	0.25411	0.21951	0.07754	0.35142
CSP6	0	0.14286	0.14286	0.02556	0.14048	0.04503	0.02059	0.0446	0.04203
CSP7	0	0.14286	0.14286	0.18254	0.14048	0.04503	0.05507	0.1362	0.04203
cloud servies	0	0	0	0	0	0	0	0	0
Ease.	0.83333	0	1	0.85714	0.5	0.5	0.5	0.5	0.5
Flex.	0.16667	1	0	0.14286	0.5	0.5	0.5	0.5	0.5

VM Cost	0.5	0.85714	0.8	0	1	0.33333	0.5	0.5	0.33333
Tra Cost	0.5	0.14286	0.2	1	0	0.66667	0.5	0.5	0.66667
No. of Pros.	0.5	0.5	0.1	0.8	0.75	0	1	0.16667	0.16667
RAM	0.5	0.5	0.9	0.2	0.25	0	0	0.83333	0.83333
SS	0.5	0.9	0.9	0.88889	0.5	0.83333	0.9	0	1
No. of VM	0.5	0.1	0.1	0.11111	0.5	0.16667	0.1	1	0

İn the following table, the ANP method result for the weighted matrix given:

In the following weighted super matrix, in this matrix the importance for each criterion and CSPs compared according to the CSPs:

	CSP1	CSP2	CSP3	CSP4	CSP5	CSP6	CSP7
CSP1	0	0	0	0	0	0	0
CSP2	0	0	0	0	0	0	0
CSP3	0	0	0	0	0	0	0
CSP4	0	0	0	0	0	0	0
CSP5	0	0	0	0	0	0	0
CSP6	0	0	0	0	0	0	0
CSP7	0	0	0	0	0	0	0
	0	0	0	0	0	0	0
Ease.	0.125	0.125	0.125	0.125	0.125	0.125	0.125
Flex.	0.125	0.125	0.125	0.125	0.125	0.125	0.125
VM Cost	0.16667	0.21429	0.21429	0.225	0.225	0.0625	0.21875
Tra Cost	0.08333	0.03571	0.03571	0.025	0.025	0.1875	0.03125
No. of Pros.	0.16667	0.025	0.05	0.03571	0.0625	0.125	0.05
RAM	0.08333	0.225	0.2	0.21429	0.1875	0.125	0.2
SS	0.02778	0.025	0.225	0.03571	0.125	0.125	0.05
No. of VM	0.22222	0.225	0.025	0.21429	0.125	0.125	0.2

in the following weighted super matrix 2 , in this matrix the importance for each criterion and CSPs compared according to the criterion:

	cloud services	Ease.	Flex.	VM Cost	Tra Cost	No. of Pros.	RAM	SS	No. of VM
CSP1	0	0.02857	0.02857	0.01143	0.03771	0.05741	0.01928	0.05397	0.02614
CSP2	0	0.02857	0.02857	0.04056	0.03771	0.05952	0.068	0.05228	0.05224
CSP3	0	0.02857	0.02857	0.02931	0.0228	0.01126	0.01132	0.01189	0.00841
CSP4	0	0.02857	0.02857	0.03651	0.0228	0.03578	0.04237	0.03019	0.02612
CSP5	0	0.02857	0.02857	0.04056	0.0228	0.06353	0.0439	0.01551	0.07029
CSP6	0	0.02857	0.02857	0.00511	0.0281	0.01126	0.00412	0.00892	0.00841
CSP7	0	0.02857	0.02857	0.03651	0.0281	0.01126	0.01101	0.02724	0.00841
cloud services	0	0	0	0	0	0	0	0	0
Ease.	0.20833	0	0.2	0.17143	0.1	0.125	0.1	0.1	0.1
Flex.	0.04167	0.2	0	0.02857	0.1	0.125	0.1	0.1	0.1
VM Cost	0.125	0.17143	0.16	0	0.2	0.08333	0.1	0.1	0.06667
Tra Cost	0.125	0.02857	0.04	0.2	0	0.16667	0.1	0.1	0.13333
No. of Pros.	0.125	0.1	0.02	0.16	0.15	0	0.2	0.03333	0.03333
RAM	0.125	0.1	0.18	0.04	0.05	0	0	0.16667	0.16667
SS	0.125	0.18	0.18	0.17778	0.1	0.20833	0.18	0	0.2
No. of VM	0.125	0.02	0.02	0.02222	0.1	0.04167	0.02	0.2	0

5. APPENDIX B

COMPARING RESULTS

In the following the programming code used in the comparison algorithm:

```
#include <stdio.h>
int main()
{
int
data[7][6]={{3,2,3,3,2,2},{1,1,1,1,1,1},{6,6,6,6,6,7},{4,3,4,2,4,4},{2,5,2,4,5,5},
     int i,j,k,y,max,ord=1,rang;
     float perhan[7][7];
     printf("\n");

            printf("\t CPSs   ||\t ANP      AHP    ELECTRE   PROMETHEE   TOPSIS
            VIKOR //\n\t");

        for(i=0;i<7;i++)
        {
          printf(" CPS %d ||   ",i+1);

            for(j=0;j<6;j++)
            {
          printf("\t %d  ",data[i][j]);
            }
        printf("\n\t");
        }
          for(i=0;i<7;i++)
        {
            for(j=0;j<7;j++)
            {
              relt[i][j]=0;
            }
        }
    printf("\t// ******************** Output 1 Part 1 ********************//\n\t

    for(i=0;i<7;i++)
        {
         for(j=0;j<6;j++)
           {
         switch(data[i][j])
           {
         case 1 :
             relt[i][0]+=1;
             break;
         case 2 :
             relt[i][1]+=1;
             break;
         case 3 :
             relt[i][2]+=1;
             break;
```

```
            case 4:
                relt[i][3]+=1;
                break;
            case 5 :
                relt[i][4]+=1;
                break;
            case 6 :
                relt[i][5]+=1;
                break;
            case 7:
                relt[i][6]+=1;
                break;
           }
           }
           }  // *******************************************************
             for(i=0;i<7;i++)
           {
           printf(" CPS %d ||   ",i+1);

               for(j=0;j<7;j++)
           {
                printf(" %d ,",relt[i][j]);
                perhan[i][j]=float((relt[i][j]/6.0)*100.0);
            }
                printf("\n\t");
           }
            printf("// ******************** Output 2 Part 1
********************************//\
            for(i=0;i<7;i++)
           {
               printf(" CPS %d ||   ",i+1);
               for(j=0;j<7;j++)
              {
                printf(" %.2f ",perhan[i][j]);
              }
                printf("\n\t");
           }
           printf("// ************* Output 1 of 2 ******************//\n")
             for(i=0;i<7;i++)
           {
           rang=i+1;
           y=0;
                max=relt[0][i];
                ord=1;
               for(j=1;j<7;j++)
         {
           if (max<relt[j][i])
            {
            max=relt[j][i];
            ord=j+1;
            }
         }
             rangk[i][0]=ord ,rangk[i][1]=max,rangk[i][2]=rang;
           }
            for(i=0;i<7;i++)
```

```
        {     printf("\n\t");
  if(perhan[i][0]>=50.00 || perhan[i][1]>=50.00 ||perhan[i][2]>=50.00
||perhan[i {
             printf(" CPS %d ||  ",i+1);
             for(j=0;j<7;j++)
            {
              printf(" %3.2f ",perhan[i][j]);
            }
             }
             else
             {
  printf(" \n \t Note: \n\t\tThe CPS Number %d is cancling \n\t  ",i+1);
             continue;
        }
             }

           printf("\n\t// ******************* Output 2 Part ********************

                printf("|| Name OF CPS || MAX OF ||  Rank  ||\n\t");
                printf("|| ============================== ||\n\t");
     for(i=0;i<7;i++)
        {       printf("||  CPS");
             for(j=0;j<3;j++)
             {
                printf("   %d    ||",rangk[i][j]);
             }
         printf("\n\t");
        }



   return 0;
  }
```