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MCDM Approach for the Adoption of Best Cloud

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ABSTRACT

ANP is a powerful tool in multi-criteria decision making. In this research, the performances of public cloud, private cloud and hybrid clouds are analyzed. This tool is used to encapsulate the interdependences in different level of decision attribute. The decision problem is structured in a hierarchical manner and the enablers, determinants and dimensions are linked with the alternatives. The current study is based on the adoption of the best cloud computing i.e. Public cloud, private cloud and hybrid cloud. Based on the literature survey the determinants, dimensions and enablers have been derived. Super matrices have been formed and then the overall weighted effectiveness of cloud computing has been found out, which will give an indication of the performances of the cloud computing. Overall weighted effectiveness was highest for public cloud and then hybrid cloud followed by private cloud

Key words: ANP, Cloud computing, Public Cloud, private Cloud, Hybrid cloud

1. INTRODUCTION

The emerging waves of globalization and liberation have intensified competition in cloud computing services. Industries are going for using cloud services ANP modeling can be considered for making decision (Saaty, 2005, Saaty Vargas, 2006). Effectiveness of cloud computing is mainly depend on the factors, reliability, scalability privacy and access control [1]. The factors like data security, storage security, information security and access management also affect the system [1].

The basic structure of ANP is a network having clusters and connecting nodes. A pair wise comparison and judgment are made to make a decision. The processing is developed between the elements and analysis is done based on the dependence of the elements present. An ANP network can include source node, intermediate nodes and sink nodes. A source node is on origin of paths of influence in the network. The sink node is a destination of paths of influence of the network. Intermediate nodes are residing between source node and destination node. We are doing things consciously or unconsciously by taking some decisions. Based on the information from literature and elicitations of experts this research has been pursued. In the ANP, ratio scale priority vectors derived from pair-wise comparison matrices are not synthesized linearly. An improved super matrix technique has been explored to synthesize ratio scales. Each ratio scale is appropriately introduced as a column in a matrix to represent the impact of elements in a cluster on an element in another cluster or one element in another cluster. The super matrix is composed of several sub- matrices each its column is a principal Eigen vector that represents the impact of all elements in a cluster on each of the elements in another cluster. There is no requirement that every elements of a cluster has an influence on an element in another cluster. In such a case these elements are given a zero value for their contribution. The super matrix which is composed of ratio scale priority vectors derived from pair –wise comparison matrices and the zero vectors, must be stochastic to obtain meaningful limiting results. The super matrix has clusters .Each block of column vectors are weighted by the priority of the corresponding cluster with their elements displayed vertically on the left side of the matrix horizontally at the top of the matrix. To ensure that this matrix is stochastic we need to compare clusters themselves that are on the left with respect to their impact on each cluster at the top. The resulting priorities of the clusters are then used to weight column vector clusters on the left with respect to the corresponding cluster on the top. Thus super matrix is column stochastic. ANP also uses a pair-wise comparison matrix to obtain ratio scale.

2. LITERATURE SURVEY

ANP is an optimal decision making tool. In this approach interrelationships between all possible alternatives are considered. All influencing factors affect the optimality of the choice [Saaty, 2006, Chenetal, 2008]. ANP can be considered as a multi-criteria decision making technique [Saaty, 2006]. Intangible aspects are considered in ANP by taking pair-wise comparison [Saaty, 1999]. ANP can be selected due to its suitability in offering solutions in a complex multi-criteria decision environment [Bottero & Modini, 2008]. The decision problem is represented in the top level hierarchy and the determinants, dimensions and alternatives and represented in the bottom level. The interdependence is revealed through the network structure. Experience and knowledge is necessary for ANP. Pair wise comparative judgment is done based on the influence of the considered elements. ANP is used for problems which can't here structured hierarchy. Networks don't have to be linear from the top to bottom. ANP uses network for which it is not necessary to specify the levels. In ANP, levels are replaced by cluster. In the ANP ratio scale priority vectors derived from pair wise comparison matrices are not synthesized linearly as in AHP. Saaty has an improved "super matrix" technique to synthesize ratio scale. Cloud computing is the newly developing technology having the ability to reduce the cost. Implementation of cloud computing has some issues related to its security. Data leakage is one of the issues in cloud computing. Cloud providers can add more resources to protect themselves. Cloud datacenters are throughout the world. Through internet the cloud computing facilities are availed by consumers.

Due to the simple apparently cheap and scalable nature, cloud computing is deployed in IT systems. To support large number of small applications, scalable multitenant database management systems running on a cluster of servers become critical in nature. In large multitenant systems the ability to migrate a tenant's database is an important feature, which allows effective cloud balancing and elasticity for minimizing the operating cost and the efficient sharing of the system resources amongst the tenants. Changing demands for data is related with storage scaling. Scalability is the main reason for using cloud computing [3]

Data security must be strongly considered in cloud. Privacy requirement and data encryption is depends on the performance of cloud [1]

Privacy is very important in e-commerce applications. Identification, authorization of data like password, user rights etc are critical for ensuring authenticity of users and proper access to resources. All cloud services requires mechanisms like authentication, authorization and auditing. Access control is essential to protect decision requests, Information security and privacy concerns cloud service in business critical applications. Standardization is also essential in cloud services. Privacy jurisdictions are different in different countries.

The main objective of security measurements are effectiveness, correctness and efficiency of security control. Cloud storage systems generally have hundreds of data servers. Same information may be stored in multiple machines. More them are power supplies may be therefore servers having same data. Due to multi tenancy architecture the IT management cost per user can be reduced. Interoperability challenges can be viewed from the perspective of service providers. Connectivity Openness to computing power and information availability through the cloud promotes industrialization. Reliability should be carefully considered by the cloud service providers. Data provenance means the data has integrity and accuracy data remanence is the representation of data that has been erased or removed. Data lineage refers following the path of data and is important for an auditor's assurance [1]. Access management practices to improve operational efficiency to comply with regulatory, privacy and data protection requirements [1]. Access management consists of authentication-process of verifying the identity of a user or system. Authorization- Process of determining the privileges the user is entitled to once the identity is established. Auditing is the process of review and examination of authentication & authorization and adequacy of identity & access management [1].

3. METHODOLOGY

ANP hierarchy for cloud computing environment is shown in figure1. The determinant represents the aspects to achieve objective of the problem. Determinants act as motivators. Determinants of cloud computing services are considered as scalability reliability, privacy and access control. Dimensions are the fields in which the objectives have aftereffects. Here the dimensions considered are data security (DS), storage security (SS), information security (IS) and access management (AM). Alternatives considered are public cloud (PC), private cloud (PRC) and hybrid cloud (HC).

The objective is to enhance the adaption of cloud computing deployment model. The determinants are posted followed by dimensions. Enablers assist in achieving dimensions and have interdependences. That is shown as arrow arching back to the enablers' decision level

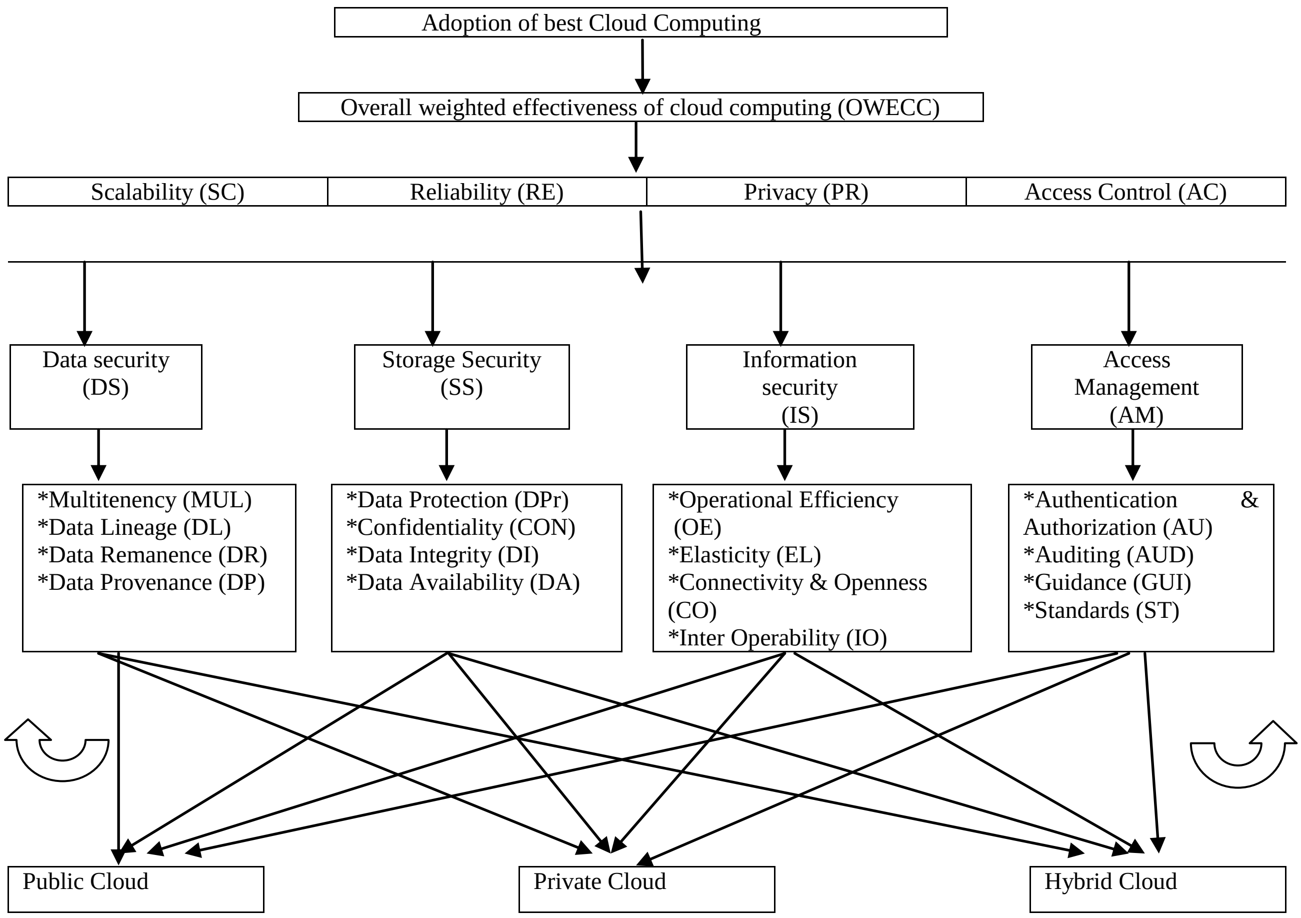

Figure 1: ANP model for cloud computing

4. IMPLEMENTATION PROCEDURE

This research has been pursued as nine step approach as shown herewith.

Step 1:- Problem formulations

The decision problem adoption of best cloud computing deployment model is structured with the four determinants scalability, reliability, privacy and access control. It is followed by four dimensions data security, storage security, information security and access management. The enablers for data security are multitenency, data lineage, and data reminance & data provenance. Enablers for storage security are data protection, confidentiality, data integrity, data availability. Enablers for information security are operational efficiency, elasticity, connectivity & openness & interoperability. Enablers for access management are Authentication & Authorization, Auditing guidance& standards. Alternatives are public cloud, private cloud & hybrid cloud

Step 2:- Pair-wise comparison of the determinants

Comparisons have been made to establish the relative importance of determinants in achieving the objective. Judgments are expressed numerically as follows. A scale of 1-9 was used to compare two options (Saaty, 1996) comparison values are as shown. 1-represents equal important 3-moderate important of one over another. 5-strong or essential important. 7- Very strong or demonstrated important. 9- Extreme important. 2,4,6,8 are intermediate values. A reciprocal pair-wise comparison is designated carefully by fundamental scale. The judgment use reciprocals for inverse comparisons. Decisions or judgment are verbally given and the corresponding number is associated with that decision. A reciprocal was to indicate row component is weak than column component i.e. in a matrix $a_{ij}+a_{ji}=1$. Matrix pair wise comparison is shown in Table.1

Eigen vector of matrix is found out and its relative priority of criteria is measured. For calculating the average of Eigen values, random consistency index (CI) is calculated using the formula CI=λ-n/n-1 where n is order of its matrix. Random index RI is considered as 0.9 for a 4*4 matrix and 0.58 for 3*3 matrixes. Then CR=CI/RI <0.1(Saaty, 2003). For the computation of Eigen vectors, the elements are normalized by dividing it with the column sum. MATLAB was used for finding the Eigen values. The eigenvector are the determinants weighted priorities and is used for the calculation of OWECC for the service alternatives.

Table 1:- PAIR-wise comparison of determinants

	Scalability SC	Reliability RL	Privacy PR	Access control AC	Eigen vector
SC	1.00	0.11	3.00	0.13	0.079
RE	9.00	1.00	7.00	2.00	0.511
PR	0.33	0.14	1.00	0.13	0.048
AC	8.00	0.50	8.00	1.00	0.0363

Step 3:- Pair-wise comparison of dimension

The four dimensions data security (DS), storage security (SS), information security (IS) and access management (AM) and its pair-wise comparison matrix was prepared. The relative importance of each of it was calculated. Eigen vectors are determined as detailed in the earlier session. Eigen vectors are posted as P_{ja} in Table 8. The values of the pair-wise comparison are shown in the Table2.

Table 2:- pair-wise comparison of dimensions with respect to access control

Access Control	Data security DS	Storage security SS	Information security IS	Access management Am	Eigen vector
DS	1.00	5.00	9.00	6.00	0.657
SS	0.20	1.00	0.50	2.00	0.120
IS	0.11	2.00	1.00	2.00	0.146
AM	0.16	0.50	0.50	1.00	0.077

Step 4:- PAIR-WISE COMPARISON MATRICES BETWEEN COMPONENTs/ENABLERS LEVEL.

The decision makers compare two components at a time with respect to an upper level criterion. Pair-wise comparisons of elements at each level are conducted with respect to relative influence towards the upper level criterion. Pair-wise comparison matrix for Data security under access control is shown in Table 3. The relative importance of multi tenancy when compared to Data Lineage, (DL) Data Remanence, (DR) and Data Provenance with respect to data security and access control is shown in Table 4. The total number of pair-wise comparison matrices depends on the number of determinants and the dimension in the ANP network. Sixteen pair-wise comparison matrices are formed and Eigen vectors obtained are taken as $A^{D}kja$ in Table 8.

Table 3:- pair-wise comparison of matrix for data secutity under access control

Access Control Data Security	Multitenency (MUL)	Data lineage (DL)	Data remenance (DR)	Data provenance (DP)	Eigen vector
MUL	1.00	4.00	0.20	0.50	0.143
DL	0.25	1.00	0.11	0.25	0.052
DR	5.00	9.00	1.00	3.00	0.586
DP	2.00	4.00	0.33	1.00	0.219

Step 5:- Pair-wise comparison matrices of interdependences.

Considering the interdependence among the enablers a pair-wise comparison is made. One such comparison is shown in Table 4. Table 4 represent the result of data security, access control cluster with multi tenancy as the control attribute over other enablers. From Table 4 it is observed that data lineage has the maximum impact on data security access control clusters (0.765). And the minimum is for data remenance (0.074) i.e. Data remenance is not a problem and has less impact on access control. There will be sixteen such matrices at this level. The Eigen vectors from these matrices are used for the formation of super matrices. Sixty four matrices will be formed and these has been used in the formation of super matrix. For example the eigen vectors from Table 4 have been used in first column of super matrices in Table 6.

Table 4:-pair -wise comparison of matrix for enablers under access control data security and multitenency

Access Control Data Security Multitenency	Data Lineage (DL)	Data Remenance (DR)	Data provenance (DP)	Eigen vector
DL	1.00	8.00	7.00	0.765
DR	0.13	1.00	0.33	0.074
DP	0.14	3.00	1.00	0.161

Step 6:- Alternative evaluation

The final set of pair wise comparison was done on each of the alternatives (PC, PRC, and HC) on the enablers to influence the determinants. The number of pair-wise comparison depends upon the number of enablers. Here 16 enablers for each determinants leading 64 pair-wise matrices. One example is shown in Table 5. These Eigen vectors are used in column 7-9 of desirability indices matrix in Table 8.

Table 5:- pair -wise comparison of matrix for alternatives impact on access control datasecurity and multitenency

	Public cloud PC	Private cloud PRC	Hybrid cloud HC	Eigen vectors
PC	1.00	9.00	8.00	0.800
PRC	0.11	1.00	0.50	0.075
HC	0.13	2.00	1.00	0.124

Step 7:- Formulation of Super matrixes

A partitioned matrix which mimics the Morkov chain process is a super matrix where each sub matrix depends on the levels represented by the model. The local priority vectors are entered in the appropriate column of the super matrix. Here four determinants hence four super matrices. Super matrix 'M' for access control is shown in Table 6. The non zero values in the column relate the important weight associated with the interdependence Pair-wise comparison of matrices'

.Table6:- Super matrix m for access control before convergence

	MUL	DL	DR	DP	DPR	CON	DI	DA	OE	EL	CO	IO	AU	AUD	GUI	ST
MUL	0	0.767	0.065	0.104												
DL	0.765	0	0.735	0.665												
DR	0.074	0.085	0	0.231												
DP	0.161	0.148	0.199	0												
DPR					0	0.584	0.798	0.236								
CON					0.798	0	0.122	0.062								
DI					0.080	0.062	0	0.701								
DA					0.122	0.354	0.080	0								
OE									0	0.161	0.723	0.689				
EL									0.070	0	0.070	0.067				
CO									0.350	0.074	0	0.244				
IO									0.580	0.765	0.206	0				
AU													0	0.620	0.681	0.707
AUD													0.648	0	0.118	0.092
GUI													0.230	0.156	0	0.201
ST													0.122	0.224	0.201	0

Table7:- super-matrix m after convergence

	MUL	DL	DR	DP	DPr	CON	DI	DA	OE	EL	CO	IO	AU	AUD	GUI	ST
MUL	0.0404	0.0404	0.0404	0.0404												
DL	0.0496	0.0496	0.0496	0.0496												
DR	0.0109	0.0109	0.0109	0.0109												
DP	0.0160	0.0160	0.0160	0.0160												
DPr					0.0075	0.0075	0.0075	0.0075								
CON					0.0067	0.0067	0.0067	0.0067								
DI					0.0035	0.0035	0.0035	0.0035								
DA					0.0036	0.0036	0.0036	0.0036								
OE									0.0024	0.0024	0.0024	0.0024				
EL									0.0004	0.0004	0.004	0.0004				
CO									0.0014	0.0014	0.0014	0.0014				
IO									0.0020	0.0020	0.0020	0.0020				
AU													0.3969	0.3969	0.3969	0.3969
AUD													0.2903	0.2903	0.2903	0.2903
GUI													0.1661	0.1661	0.1661	0.1661
ST													0.1468	0.1468	0.1468	0.1468

To obtain long term stable sets of weights the super matrix M is made to converge. The power of super matrix M is raised to M^{k+1} where k is a large arbitrary number. By raising the power of super matrix allows for the convergence of the interdependent relationships (Meade & Sarkis, 1999). In this example convergence is reached at M^{23000} .i.e. the super matrix is raised to a power of 23000. It is observed that there is no marginal difference between M^{23000}&M^{23001} .i.e. convergence is obtained at M^{23000} and is shown in Table7. This was done by using MATLAB. The other three matrices were formed similarly.

Step 8:- Best Alternative Selection

The Desirability index Dia for an alternative i and determinant a is defined (Meade and sarkis, 1999) as per the equation (1) given.

$$D_{ia} = \sum_{J=1}^{J} \sum_{k=1}^{K_{ja}} P_{ja} A^{D} K_{ja} A^{I} k_{ja} S_{i} K_{ja} \qquad \text{----- (1)}$$

Here $P_j a$ is the relative importance weight of dimension j on the determinant 'a', A^Dkja-the relative importance weight for enabler k, dimension j and determinant a for the dependency (D) relationship between enablers levels, A^Ikja is the stabilized relative importance weight for attribute enabler K of 'j'- dimension in the determinant 'a' for interdependency (I), relationships within the attribute enablers component level. Sikja-the relative impact of cloud computing alternative paradigms i on cloud computing enabler k of dimension j of cloud computing hierarchy network.

The calculation for desirability indices for alternatives based on the scalability is shown in Table 8. The weight obtained from the pair wise comparisons of the alternatives, dimensions and weights of enablers from the converged super matrix are used. Results from step 2 are incorporated in the second column of Table 8. The fourth column contain the pair-wise comparison matrix for the relative impact of the attribute enablers on the dimensions of cloud computing. The fifth column values are the stable interdependent weight of attribute enablers obtained through super matrix convergence. The sixth, seventh and eighth column of Table 8 contain the relative weight of the three alternatives for each dimension. The desirability index (Pja*A^Dkja*A^Ikja*Sikja) of each alternative is shown in the final three column of Table 8. For the example the value corresponding to public cloud for multitenency is 0.00304 (0.657*0.143*0.0404*0.80). The final row of Table 8 is the total desirability indices of public cloud, private cloud and hybrid cloud under access control determinant. Similar analysis is carried out for other three determinants.

Table8:- **total desirability indices for access control**

Dimension	Pja	Enablers	A^Dkja	A^Ikja	Product	S1kja	S2kja	S3kja	Pc	Prc	HC
DS	0.657	MUL	0.143	0.0404	0.00578	0.800	0.075	0.124	0.00304	0.0002847	0.0004707
DS	0.657	DL	0.052	0.0496	0.00258	0.739	0.101	0.160	0.00125	0.0001711	0.0002711
DS	0.657	DR	0.586	0.0109	0.00639	0.707	0.092	0.201	0.00297	0.0003861	0.0008435
DS	0.657	DP	0.219	0.0160	0.00350	0.703	0.115	0.182	0.00162	0.0002647	0.0004190
SS	0.120	DPr	0.178	0.0075	0.00134	0.808	0.074	0.118	0.00013	0.0000119	0.0000189
SS	0.120	CON	0.690	0.0067	0.00462	0.786	0.068	0.146	0.00044	0.0000377	0.0000810
SS	0.120	DI	0.083	0.0035	0.00029	0.785	0.128	0.087	0.00003	0.0000045	0.0000030
SS	0.120	DA	0.049	0.0036	0.00018	0.765	0.074	0.161	0.00002	0.0000016	0.0000034
IS	0.146	OE	0.371	0.0024	0.00089	0.790	0.129	0.081	0.00010	0.0000168	0.0000105
IS	0.146	EL	0.270	0.0004	0.00011	0.751	0.150	0.099	0.00001	0.0000024	0.0000016
IS	0.146	CO	0.322	0.0014	0.00045	0.767	0.143	0.090	0.00005	0.0000094	0.0000059
IS	0.146	IO	0.038	0.0020	0.00008	0.719	0.113	0.168	0.00001	0.0000013	0.0000019
AM	0.077	Au	0.090	0.3969	0.03572	0.777	0.069	0.115	0.00214	0.0001898	0.0003163
AM	0.077	AUD	0.150	0.2903	0.04355	0.777	0.135	0.088	0.00261	0.0004527	0.0002951
AM	0.077	GUI	0.120	0.1661	0.01993	0.751	0.150	0.099	0.00115	0.0002302	0.0001519
AM	0.077	ST	0.639	0.1468	0.09381	0.798	0.122	0.080	0.00576	0.0008812	0.0005778
			TOTAL DESIRABILITY INDICES						0.02132	0.0029459	0.0034716

Table9:- **values of owecc & nowecc**

Alternative	scalability	Reliability	Privacy	Access control	OWECC	Normalized value for OWECC
weight	0.07900	0.5110	0.04800	0.036300		
Pc	0.20745	0.06302	0.51221	0.02132	0.080917	0.77969
Prc	0.03139	0.00595	0.05854	0.00295	0.00940	0.09058
Hc	0.02666	0.01152	0.08776	0.00347	0.01346	0.12973

Step 9:- Calculation of overall weighted Effectiveness of Cloud Computing (OWECC).

The overall weighted effectiveness of cloud computing is determined for the three alternative paradigm. The product of the desirability indices (Dia) and the relative important weight of the determinant (Ca) of the cloud computing gives the overall weighted effectiveness of cloud computing.

Ie- $OWECC_i = \sum$ Dia Ca

The total desirability indices under scalability, reliability, privacy and access control are tabulated in Table 9. For example the calculation of OWECC for public cloud is given below.

$OWECC_{pc}$= [(0.079*0.20745) + (0.511*0.6302) + (0.48*0.51221) + (0.363*002132)]

=0.080917

OWECC of public cloud is 0.080917 and its normalized value is 0.77969 which shows that public cloud is the most suitable alternative for cloud computing following hybrid cloud and private cloud computing.

5. CONCLUSION

Cloud computing is making a drastic change in the field of Information Technology. Due to this reason the IT sectors and researchers are giving more importance to reduce the issues related to cloud computing. In this paper the study is made for cloud computing environment with the aid of ANP model. It measures the relative strength and impact between elements in the network model. This decision model integrate and relies upon the characteristics of cloud computing. After making a thorough study on cloud computing the determinant, dimensions, enablers are found out. It is a tedious and time consuming task for the formulation of pair-wise comparison matrices and data acquisition. Around 184 matrices are formed for completing the study. The pair-wise comparison of criteria depends on the users knowledge and familiarity with the firm. After this study it came out that 'Public cloud' is the most important one among the three, following hybrid cloud computing and private cloud computing.

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