Selecting Cloud Deployment Model Using a Delphi Analytic Hierarchy Process (DAHP)

James Ngeru and Tridip K. Bardhan

Department of Industrial and System Engineering
Morgan State University
Baltimore, MD, USA

Corresponding Author's Email: tridip.bardhan@morgan.edu

Abstract: Cloud computing is a significant paradigm shift in information technology (IT) service offerings that has been receiving enormous attention in academic and IT industry. Recent years has seen exponential growth in cloud use adoption, where many organizations are moving their IT resources into cloud due to flexibility and low-cost. However, on account of rapid innovation and growth in cloud technologies and service providers, selecting the right cloud services, provider and strategy is becoming increasing a common challenge to organization during cloud adoption. In an attempt to address this challenge, we propose application of Delphi Analytic Hierarchy Process (DAHP) method in selecting cloud deployment model. There are several cloud deployment models and organizations must identify the right model that best suits their business needs. The proposed approach facilitates a collaborative decision making process, consisting a number of decision makers whom, with consensus facilitated by the DAHP process, identifies feasible approaches, decision making factors and ultimate selection of a cloud deployment model alternative that is based on organizational business needs and capabilities. The DAHP process is illustrated by a means of a case study. The DAHP result analysis, as was illustrated in the case study, helps in explaining and justifying the choice selected as the best cloud deployment model.

Keywords: Delphi Analytic Hierarchy Process, Cloud Deployment Model

1. Introduction

Today, many organizations are relentlessly seeking for innovative strategies and methods of conducting business that would allow them to reduce costs while improving operational efficiencies, acquire sufficient business agility and achieve competitive advantage (Ngeru, 2012). Achieving such a strategic goal involves adopting groundbreaking technological tactic that will radically change business processes, strategies and visions that will support long-term objectives. Cloud computing, which is a paradigm that is moving computing from internal managed hardware and software resources to virtualized Cloud-hosted services, is one such approach that represents an extraordinary evolution in Information Technology (IT) arena (Zhang et al., 2012). Cloud computing, which according to Lee and Nickerson (2011) "is a distributed computing model that provides computing facilities and resources to the users in an on-demand pay-as-you-go" and empowers organizations to manage IT costs while building a powerful and flexible way to acquire latest technology (Costa, 2013). An ideal cloud computing model depends on organizational specific business needs, which can be addressed by different services capabilities, technology, and vendors.

However, there are several cloud computing service models that organizations can adopt. Example of such models may include vendor-provided services that can be accessed through the Internet or a private network; internal enterprise computing architectures sculpted after vendor clouds; and hybrid models that mix vendor cloud services, internal cloud architectures, and classic IT infrastructure (Lee & Nickerson, 2011). Since each cloud service model architecture offers different advantages and constraints, many organizations find it as a great decision challenge when identifying the right service model that will optimally address their business needs.

To address this challenge, this paper proposes application of multi-criteria decision approach in selection of the right cloud computing service model. The article first outlines a Delphi Analytic Hierarchy Process (DAHP) decision approach. The DAHP process is then illustrated through a simple factual case study performed in a software company pursuing cloud strategy adoption.

2. Cloud Computing Overview

In early 1960's, John McCarthy established Utility Computing concept by predicting that "Computation may someday be organized as a public utility" (Brunzel & Di Giacomo, 2010). Today, utility computing has found its way where many computing resources are being transformed to models that consists of commoditized services that are delivered in a similar fashion to traditional utilities such as water, electricity, gas, and telephony, and consumers can access these services based on their requirements regardless of where these services are hosted or how they are delivered (Buyya et al., 2009). In recent years, one of the incredible paradigm breakthrough in the history of computing is cloud computing. Cloud computing is a model that delivers infrastructure, platform and software as services, which are referred to as Infrastructure as a Service (IaaS), Platform as a Service (PaaS), and Software as a Service (SaaS). In cloud computing model, hardware and software resources are the delivering basis for IaaS and PaaS and forms the lower layers, whereas the SaaS forms the top layer that focuses on application services using the services provided by the lower layers (see Figure 1). These services are generally developed and provided by different third party services such as Amazon, Apple, Cisco, Citrix, IBM, Joyent, Google, Microsoft, Rackspace, Salesforce.com, SunGard, etc. (Shawky, 2013; Zhang et al., 2012).

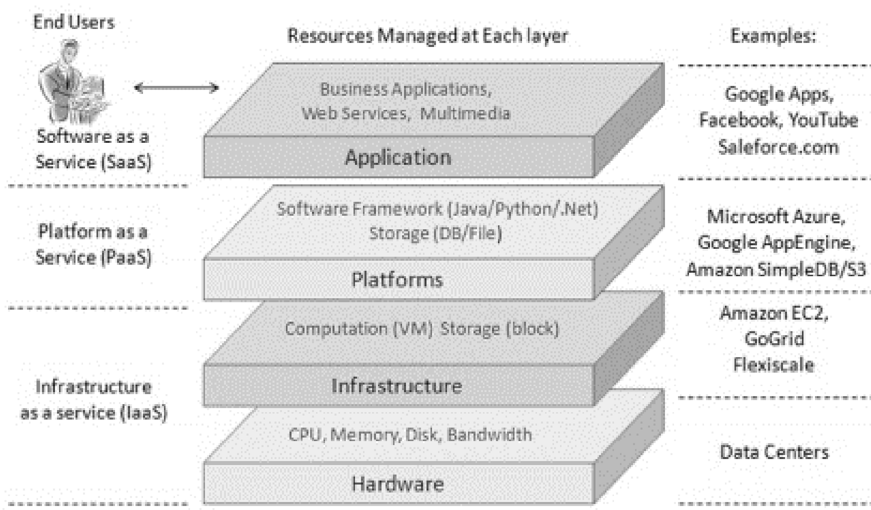


Figure 1. Cloud Computing Architecture (Zhang et al., 2010)

Many companies are now moving to cloud computing service models as they are realizing that traditional computing service models are not adequate enough to keep up with today's business environment, which incidentally is becoming increasingly complex, competitive and characterized by ever increasing customers' expectations. Some of the salient features and benefits are compelling the rapid adoption and growth of cloud computing including: (i) *multi-tenacity*, which means multiple users from different organizations entities can access the infrastructure simultaneously. This allows cloud services provider to take significant cost advantages and profitability, which in turn is passed-on to cloud users and thus a cost-effective solution; (ii) *utility based pricing*, cloud computing offers a pricing model that is based on usage or subscription-based and thus fixed costs are converted to variable costs; (iii) *elasticity of resources*, the self-organizing aspect of cloud computing provides agility and flexibility to cloud consumers since services are available on demand and consumers can upscale/downscale the capacity according to their needs and without incurring additional capital expenditure; (iv) *ease of implementation*, where building applications in cloud is much easier and quicker than building new applications and data centers; (v) *Geo-distribution* and *ubiquitous network access*, where the cloud services are accessible from anywhere and any device that has internet connectivity. Also, many cloud services providers have multiple data centers that are globally distributed to improve network performance; and (vi) *carbon foot print reduction*, resource pooling nature of cloud computing and technological advancement reduces number of computing servers and thus energy consumption. (KPMG International, 2011; Zhang et al., 2010). Additional factors fostering the growth of the cloud computing are rising computer penetration, improvement in bandwidth availability, innovations in commodity server market, and improvements in storage technology (KPMG International, 2011).

However, although cloud computing offers a number of fascinating benefits, it also presents some unique challenges. Some of the key and common challenges associated with cloud computing implementation may include privacy and security assurance; reliability and availability; transition and execution risk; regulatory ambiguity, especially internationally; costs associated with a migration from legacy infrastructure to the Cloud; tax issues and; cultural resistance (KPMG International, 2011). Moreover, it is very essential for organizations to identify and define methods and techniques to apply during cloud computing implementation in order to leverage preceding investments and benefits of cloud computing. This is however a cumbersome task as many challenges arise during implementation. Shawky (2013) identified some of these challenges that included designing migration plans, evaluating them and moving applications to a targeted cloud computing model. Li et al. (2013) also termed the task of evaluating the performance of a cloud service as problematic as it is fundamentally important for potential cloud consumers to know the quality of services they will consume and pay for. Furthermore, defining a migration strategy requires thoughtful considerations of business priorities that will lead to a strategy that strikes a fine balance between costs and meeting business priorities (Shawky, 2013). One of the significant yet basic entry challenge, besides identifying cloud service providers and resources to handover to cloud services, involves identifying the cloud deployment model to adopt. There are different approaches of adopting cloud computing (see examples in Figure 2) each with its own benefit and drawbacks. These types of cloud include (Dialogic Corporation, 2010; KPMG International, 2011; Zhang et al., 2010):

(i). Public clouds - Type of the cloud where the service providers offers their resources as services to the general public and are dynamically provisioned on a fine-grained, self-service basis over the Internet, and through web applications/web services. For example, Amazon EC2 cloud, an Amazon's service that rents storage space to businesses, governments, and individuals. Some of the advantages of this type of cloud type include no initial capital investment on infrastructure and shifting of risks to infrastructure providers. Some drawbacks may include lack of fine-grained control over data, network and security settings that inhibits their effectiveness in many business situations.

(ii). Private Clouds - Type of the Cloud that is exclusively set up for a single organization. The cloud infrastructure may be set-up on premise or off-premise, managed internally or by third-party service providers. In this type of the cloud, scalable resources and virtual applications are pooled together and made accessible for cloud users to share and use. This type of cloud deployment presents benefits of high level of security and control since only organization and designated stakeholders have access to the private cloud. However, private cloud is expensive compared to public cloud.

(iii). Hybrid Clouds – This type of cloud is generally best-of-breed and essentially a mixture of at least two clouds, such as a combination of public, private, or community. The cloud infrastructure may consist of a number of clouds of any type, though the clouds have the ability via their interfaces to permit data and/or applications to cross from one cloud to another. A hybrid cloud model supports the necessity to retain some data in an organization, and also the need to offer services in the cloud.

(iv). Community Cloud - A type of cloud which is established among two or more organizations that have similar cloud requirements.

(v). Virtual Private cloud - This type of cloud deployment model addresses the limitation of both private and public clouds. The model adds another platform layer running on top of public cloud, leveraging the Virtual Private Network (VPN) technology, which allows design of unique topologies and security settings such as firewalls settings. Due to the virtualized network layer, which adds layer of security, organizations are able to transition proprietary service infrastructure to cloud based infrastructure.

When considering which cloud deployment model to adopt, it is very necessary for the organizations to evaluate the cloud services while paying a close attention the reduction of risk and trade-off between performance and cost (Song, 2013). Many different factors that represent the overall performance and the main feature must be identified and systematically evaluated against each cloud deployment model. Some of these factors are summarized in Table 1. The list of factors identified in Table 1 is not exhaustive but represents most of the common factors that should be taken into consideration during cloud adoption. The set of factors and their respective weight varies from organization to organization and each situation is unique. It's quite obvious that selection of the cloud deployment model is a complex decision as it involves evaluation of several alternatives while taking into consideration a set of multiple factors. A common decision approach recommended on such decision scenario involving several alternatives and a number of criteria is to use Multi-Criteria Decision Methods (MCDM). Zardari et al. (2014) proposed use of the MCDM and specifically Analytic Hierarchy Process (AHP) in prioritization of obstacles and resolution tactics during could adoption process. They further noted that despite the fact that the cloud use has been rapidly growing, there has been general lack of systematic decision methodologies to support cloud adoption, such as in engineering requirements and early mitigation of risks in the cloud adoption. Whaiduzzaman et al.

(2014) reviewed appropriateness of several Multi-criteria Decision Analysis (MCDA) techniques during cloud computing service selection. In their review, they also concurred that organizations must be able to select appropriate cloud service according to the business needs, and thus MCDA methods are appropriate in decisions related to cloud adoption. In this paper, we propose use of a unique approach of Delphi Analytic Hierarchy Process (DAHP).

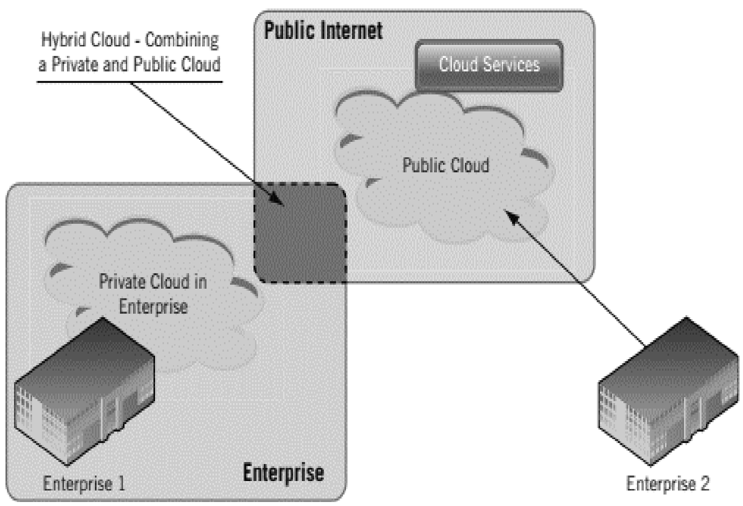


Figure 2. Public, Private, and Hybrid Cloud Deployment Example (Dialogic Corporation, 2010)

Table 1. Summary of Factors Considered during Cloud Computing Deployment Model Selection (Buyya et al., 2009; Hauck et al., 2010; Marinescu, 2013; Zardari et al., 2014)

Factor	Description
Security	Expectations that the cloud model will only provide access only to authorized, authenticated users, and those users need to be able to trust that their data is secure
Usability	Extent to which a the cloud system or service can be used by specified users to achieve specified goals with effectiveness, efficiency, and satisfaction in a specified context of use
Serviceability	Ability of infrastructure components to be updated or even replaced without disrupting its characteristics including availability and security
Availability	The degree to which a system is operable, that is, capable of producing responses to submitted requests.
Resilience	Ability to diminish the scale and/or duration of disruptive events to a critical infrastructure – Should have ability to anticipate, absorb, adapt to and rapidly recover from disruptive event
Reliability	Expectation that applications will not fail and most importantly they do not lose data. The architecture is designed such that applications will continue to operate and their data remains intact despite the failure of one or more of the servers or virtual machines onto which they are decomposed
Scalability	The cloud model should allow the scaling of applications and other resources with workload demands to allow performance and compliance with service levels remain on target. This requires applications and their data to be loosely coupled to maximize scalability. The model should be elastic to allow scaling down as workloads diminish in order to not run up the cost of deploying in the cloud
Interoperability	Interoperability aim is to realize the seamless fluid data across clouds and between cloud and local applications. Essentially, the cloud computing strategy should allow: • Optimizing of IT assets and computing resources, allow organization to keep in-house IT assets and capabilities associated with their core competencies while outsourcing

Factor	Description
	marginal functions and activities on to the cloud. • Can allow outsource a number of marginal functions to cloud services offered by different vendors. Standardization appears to be a good solution to address the interoperability issue
Complexity	The cloud model should not introduce complexities or to intricate, such as by introducing virtual applications and process that can affect the performance and serviceability
Cost	Cost of associated with system implementation as well as maintenance.

3. Proposed Approach - Delphi Analytic Hierarchy Process (DAHP)

Selecting a cloud deployment model can be regarded as a complex decision making process. It consists of multiple criteria and may also involve a number of decision makers. It is quite important that an informed decision must be made at this early adoption stage to allow organization select the most effective and efficient cloud strategy. Thus, the problem requires an elaborate and systematic approach that would allow participants involved in this process to evaluate different alternatives while considering multiple sets of factors, and expressing their preferences on factors.

This paper introduces a Delphi Analytic Hierarchy process (DAHP) framework that would allow organizations to determine what cloud deployment approach that best suits their business needs by evaluating feasible alternatives using multiple criteria.

Delphi method, which was introduced by Rand Corporation in 1960's (Brown & RAND Corp, 1968) is an iterative process designed to achieve consensus among a group of knowledgeable individuals on a particular topic (Taleai Mohammad, 2008). Essentially, Delphi process involves collecting judgments through questioning individuals knowledgeable about the subject; collating the informed judgments and to refine the questions; and lastly, feedback of the collated information anonymously to the participants. The process is then repeated until a reasonable consensus is reached, by requesting participant to use anonymous feedback to reconsider their response to the refined questions (Tavana et al., 1993). This paper applies both conventional-Delphi and modified-Delphi methods. In conventional-Delphi method, participants are presented with open questionnaire to identify the factors and elicit their opinions, but in modified approach, participants are presented with factors and invited to express their personal opinions towards each factor. The alternatives to be evaluated are already pre-determined, and through literature review, factors that ought to be considered are identified. The Delphi participants are therefore presented with alternatives and factors, and requested to select factors they think are most important and compare them against each other, as well as the alternatives. The participants are also presented with a chance to suggest additional factors that they may consider important with respect to the objective. The outcome from this Delphi process is then used in hierarchical processing procedure in AHP.

AHP is multi-criteria decision approach developed by Thomas L. Saaty (1980). The AHP approach is a widely and well acknowledged in several disciplines, and have been used in making decisions in complex situations, based on variables that do not have exact numerical consequences (Sureshchandar & Leisten, 2006). The technique allows consideration of multiple factors (tangible or intangible) by assuming that all factors have some utility that is additive and thus assigns relative importance weights to these factors (Ngeru et al., 2011). AHP technique employs qualitative and quantitative methods, where it applies qualitative methods to decompose an unstructured into a systematic decision hierarchy whereas quantitative methods are used for comprehensive analysis and to validate the consistency of responses (Sureshchandar & Leisten, 2006). The decision making process following AHP approach generally involves four steps (Ngeru, 2012; Ngeru et al., 2011; Ngeru et al., 2009): (i) Establishment of hierarchy structure; (ii) the calculation of the weight of the criteria of each hierarchy, in which establishing pairwise comparison matrix is established, calculating vector of priorities (i.e. proper or eigen), and testing consistency; and (3) calculation of weight of whole hierarchy

The selection of cloud deployment model may involve different actors, who are involved in the decision process. Delphi method provides the framework that allows participation and decision consensus among different actors involved in the process. Ustinovichius et al. (2007) further argued that, AHP pairwise comparison can only be considered sufficiently reliable if the judgment of different participants is in concordance, thus, AHP application is justified only if a group of participants has reached a compromise solution. Delphi method overcomes this challenge by improving the effectiveness of AHP in contributing to group consensus and decision making.

The DAHP method presented in this article consists of the following seven steps; (i) Problem formulation and factor identification; (ii) Forming evaluation panel; (iii) Defining evaluation Criteria; (iv) Structuring problem hierarchy; (v) Pairwise comparison; (vi) Aggregating and normalizing results; (vii) Calculate globe weight and rank alternative. (Figure 3)

To illustrate the DAHP framework application, a simple but actual case study conducted in a software development company is presented.

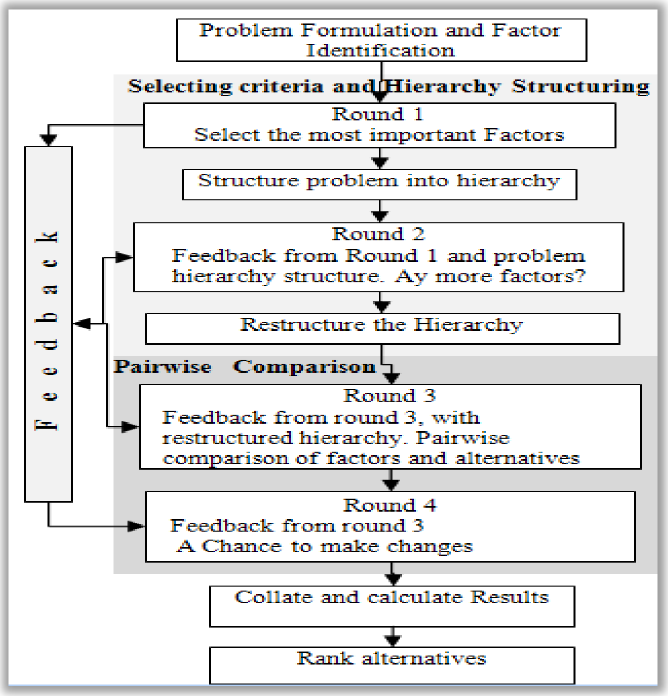


Figure 3. Structure of DAHP Evaluation Framework

4. Application of DAHP

To illustrate the process and application of DAHP framework, a simple case study is presented on this paper. The case study was conducted in a software development company. The company was considering whether to move its staging and development environments to cloud. The company provides software products in a SaaS model internationally, and thus consists on several production environments, virtualized in cloud using different cloud service providers and amalgamation of several cloud application, and hosted on different strategic global locations. The cloud deployment model on production environment is complex hybrid type that is also coupled with an extra layer of security supported by Virtual Private Network (VPN). However, the development and stage environments are still on traditional service model. Some of the hardware resources that are used to support the production environment are owned by the company but located on third-party premises. When these resources are decommissioned on production environment, they are re-used to build and scale-up performance on the staging and development environments. Thus, the company must choose an appropriate cloud strategy that will offer enough benefits to justify moving away from traditional to cloud computing model, especially when considering they already have existing hardware and application resource. Some key decision makers in IT unit are hesitant to accept the move of transiting the two environments to cloud as they feel abandoning investment made on these two environments is not justifiable. On the other hand, other decision makers support some type of cloud integration to improve the agility and scalability on these environment. To overcome the decision dilemma, application of DAHP was suggested. The Delphi component of the decision framework was necessary in order to facilitate a consensual decision by aggregating the school of thoughts among the decision participants. AHP component was favored as it permits consideration of multiple alternatives and factors, where some of these factors are conflicting and it is relatively easy to implement. AHP also allows decomposition of the problem into a system of hierarchies of objectives, criteria and alternatives. The decision making process, following DAHP model involved the following phases:

Phase 1: Preparation: This phase involved identifying and reviewing different cloud deployment models and decision criteria. Also a task force made up of four members was formed and included three senior IT managers and an external IT consultant. All the four members selected had a strong IT and management background, very familiar with the company's IT architecture and substantial experience and knowledge of cloud computing principles.

Phase 2: Selecting factors and structuring problem hierarchy: - This was also the first and second Delphi rounds. First round of Delphi was to present the task force with brief description about the problem, proposed alternatives and a list and description of factors that ought to be considered to achieve the decision objective. The panel was requested to select and justify the factors that they would consider important in evaluating the presented alternatives. They were also requested for additional factors that may have been excluded from the list. From this round, the group identified nine factors that should form the decision criteria. These factors included, Security, Implementation cost, maintenance cost, Scalability, existing investment, reliability, performance, availability, and complexity. They also identified four feasible alternatives:

(i). Private deployment model - Acquire necessary additional hardware and application resources that would allow the company to build its own internal cloud, on premise and managed internally
(ii). Hybrid deployment cloud model – Develop some virtualization with existing hardware and application resources and move some services to cloud, such as storage, some of product modules etc.
(iii). Virtual Private cloud - Move everything to cloud, but similar to production environment, add additional layer of security
(iv). Traditional Service model - Continue business as usual

With necessary decision elements identified, the problem was structured into hierarchy, consisting of three clusters i.e. Decision Goal, Criteria and Alternatives. In the second round, the group was presented with anonymous feedback from round one, where they were presented with results from other members. The members were requested whether to reconsider their judgments'. The group was also presented with proposed problem hierarchy. The results from this round were similar to the result from round one, and thus, consensus on evaluation factors and final hierarchy structure formed as shown in Figure 4.

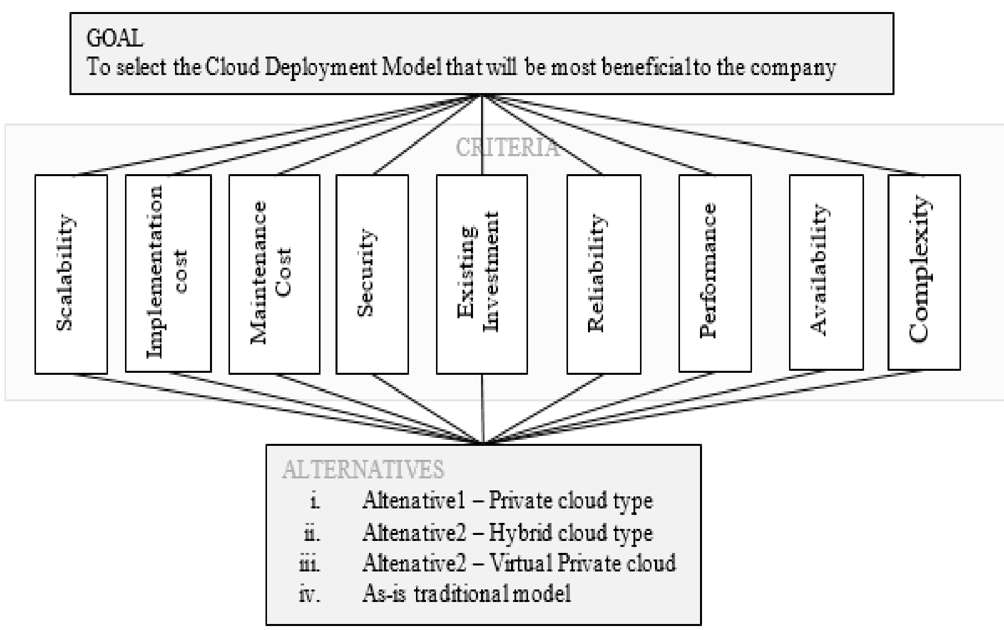


Figure 4. Cloud Approach Decision Problem Hierarchy

Phase 3: Pairwise comparison: - In this stage, pairwise comparison that included all the combinations of criteria, and alternatives relationships were performed. This phase also represented Delphi round 3 & 4 of modified Delphi. In round three, the participants were presented with instructions on how to perform pairwise comparison that was implemented using use an excel-DAHP template then transcribed to super-decision software for analysis, as shown in Figure 5 and Figure 6. The final problem hierarchy developed in the previous stage was also designed on Super-decision Software. The participants were requested to compare the alternatives, criteria according to their relative importance with respect to the parent element (criterions with respect to goal, and cloud model alternative with respect to criterions). A scale of 1-9 is used, as suggested by Saaty (1980) to quantify the strength of participant's feeling between any two alternatives with respect to a given attribute and importance of between to criterions with respect to objective, as shown in Table 2. In situation where the participants

Table 2. Saaty's Scale of Measurement for Pairwise Comparisons

Intensity of importance	Definition
1	Equal importance
3	Moderate Importance
5	Essentially or strong importance
7	Very strong or demonstrated importance
9	Absolutely Importance
2,4,6,8	Intermediate values
Note: If activity *i* has one of the above non-zero numbers assigned to it when compared with activity *j*, the j has the reciprocal value when compared with *i*	

may find it impossible to determine appropriate weight due to lack of enough information or knowledge, the two elements compared were considered as equally important. The fourth round was set as the last one, and the panel was presented with round three results and with an option to make any changes in their pairwise comparisons. Some revised their pairwise weightings, resulting to a degree of consensus improvement.

Stage 4: Aggregating results: - factor preferences varied from one panel member to another, hence; there was need to aggregate results for all participants. This was achieved by computing geometric mean method (GMM), using equation 1, below. The GMM procedure was preferred over arithmetic mean due to its ability to dampen very high or low values, which might bias arithmetic mean, and hence less affected by extreme values.

$$GM = \left(\prod_{i=1}^{n} a_i\right)^{1/n} = \sqrt[n]{a_1 \cdot a_2 \cdots a_n} \tag{1}$$

Where a_{ij} is quantified judgment by participants on a pair of factors and $i, j = 1, 2\ldots, n$

Phase 5: Calculating factor priorities, and ranking alternatives - In this stage, an AHP tool (Super decision Software) was used to calculate factor priorities and ranking alternatives, using aggregated results from previous stage. The factor priorities and alternative ranking results are presented in Figure 7 and Figure 8. More on AHP procedure can be found, in Saaty (1980). Nevertheless, calculating priorities or relative weights involves calculating vector of priorities and normalizing the results. Elements of each column are divided by the sum of that column (normalizing the column), and then eigen vector is obtained by adding elements of in each resulting row to obtain row sum, and dividing this by the elements in the row, obtaining priority or relative weight. The overall priorities are calculated by multiplying the priorities of the factors within a group by the priority of that factor's group (which are calculate in same way)

The value scores for alternatives (in Figure 7) are obtained using equation 2 below

$$Vi = \sum_{y=1}^{k} W_z T_{iz} \tag{2}$$

Where Vi is value score for alternative i, and W_z is Weight priority for Factor z ($1 \leq z \leq k$) and T_{iz} is relative weighting of alternative i supports factor z

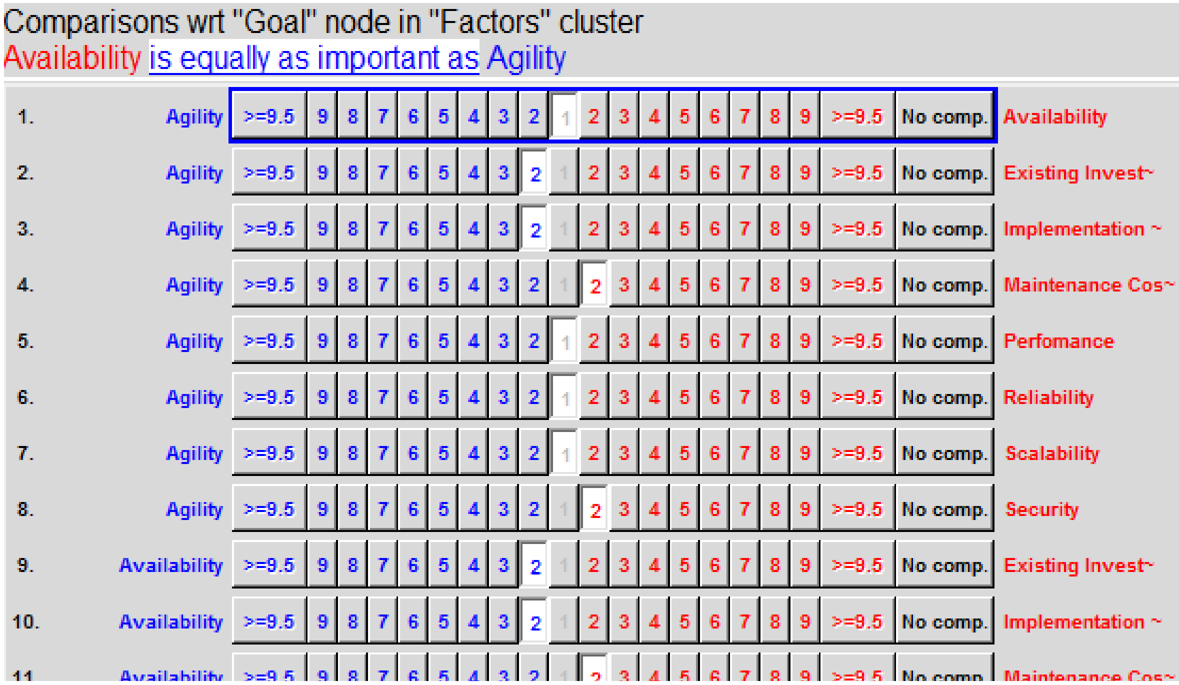


Figure 5. Pairwise Comparison of Factors on Super-Decision Tool

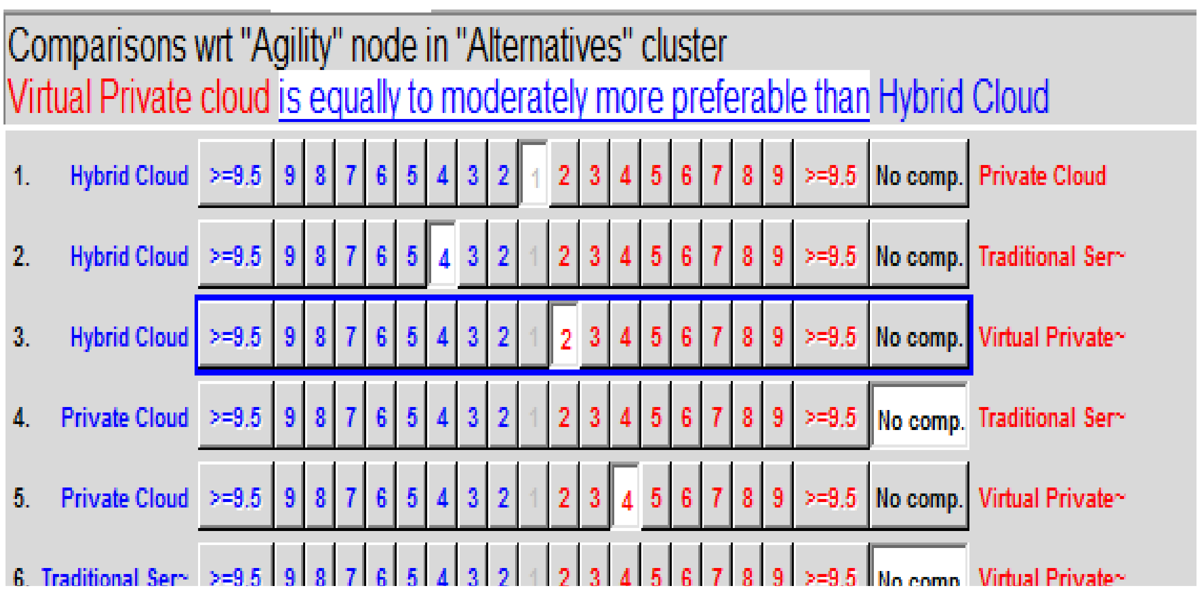
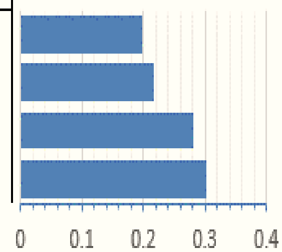


Figure 6. Sample of Pairwise Comparison of Alternatives with Respect to Factors

	Weight		
Alternatives	Global	Local	Ranking
Hybrid Cloud	0.0987	0.1974	4
Traditional Service model	0.109	0.218	3
Private Cloud	0.1408	0.2816	2
* Virtual Private cloud	0.1515	0.303	1



* Best alternative

Figure 7. Alternative Ranking Based on Value Score

	Global	Local	Rank
Scalabilty (SCA)	0.0943	0.1886	1
Availability (AVA)	0.07254	0.14508	2
Reliability (REL)	0.06718	0.13436	3
Security (SEC)	0.06045	0.1209	4
Complexity (COM)	0.04836	0.09672	5
Maintenance Cost (MAC)	0.04836	0.09672	5
Perfomance (PER)	0.04836	0.09672	5
Implentation Cost (IMC)	0.03627	0.07254	8
Existing Investment (EXI)	0.02418	0.04836	9

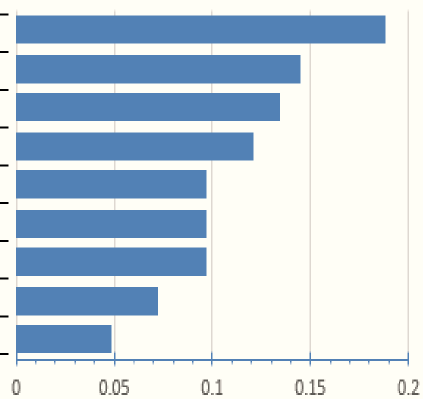


Figure 8. Local and Global (Overall) Factor Relative Weights (Priorities)

5. Results and Discussion

Use of DAHP framework provided systematic approach in selection and evaluation of cloud deployment models. As it can be observed from the case study presented, the framework facilitated a rigorous and consensual decision that ultimately led to a selection of the best alternative that best fits the company's business needs, see Figure 7. The DAHP analysis also assisted the task force to identify an organizational based criterion, and further allowed them to rank these factors with respect the decision goal, as shown in Figure 8. As seen in Figure 8, scalability, availability and reliability of the cloud strategy were valued as the top three most important factors influencing the decision. The cloud system complexity, maintenance cost, and performance were all considered to be equally important, while existing investment was considered least important to influence the decision. Additionally, with DAHP results analysis process, relationships between factors and alternatives can be explored. As it can be observed from Figure 9, it's quite obvious to see how the Virtual Private Cloud model was ranked as the best alternative. The alternative was considered to be more reliable, with good performance, low maintenance cost and not that very complex. It can also be observed that the existing traditional model scored high in terms of leveraging the existing investment, low implementation cost, and together with private cloud were considered most secure (since both were to be managed internally and hosted in-premises).

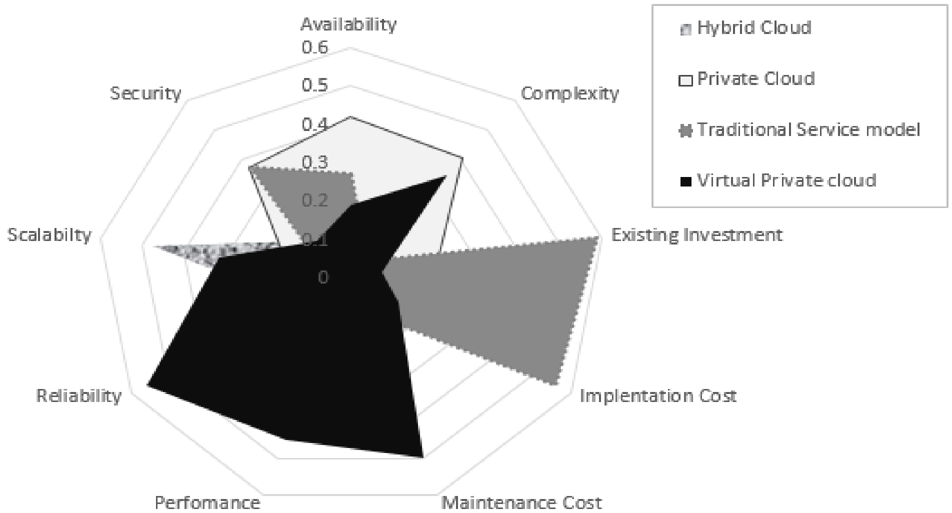


Figure 9. Radar Chart Showing Different Alternative Support Factors

6. Conclusion

In this paper, a decision making framework combining two popular decision making methods, Delphi and AHP, was presented. Application of the framework in a decision related to cloud computing adoption was illustrated through a simple case study. Adoption of cloud computing technologies is rapidly growing and while many organizations are considering implementing a cloud computing strategy, they are faced with a great decision challenge of identifying the right cloud services and deployment strategy that best suits their business needs. The DAHP decision approach presented in this paper attempts to mitigate the complexity of such decision by decomposing the decision elements and allowing several decision makers to thoroughly evaluate these elements, and make a consensual decision.

The presented decision approach can be applied in many decision scenarios such as those related in service provider selection, hardware selection or any project selection. Ongoing work includes a developing an automated tool supporting cloud adoption decision, which would allow collaborative decision process with a number of decision makers and using DAHP analysis. Additionally, in-planning is a broader study to identify more factors influencing cloud computing adoption.

7. References

Brown, B. B. & RAND Corp. (1968). Delphi Process: A Methodology Used for the Elicitation of Opinions of Experts. Ft. Belvoir: Defense Technical Information Center. Retrieved from http://handle.dtic.mil/100.2/AD675981

Brunzel, T. & Di Giacomo, D. (2010). Cloud Computing Evaluation: how it differs to traditional IT outsourcing (Masters). Jonkoping University, Sweden. Retrieved from http://www.diva-portal.org/smash/record.jsf?pid=diva2:328402

Buyya, R., Yeo, C. S., Venugopal, S., Broberg, J., & Brandic, I. (2009). Cloud computing and emerging IT platforms: Vision, hype, and reality for delivering computing as the 5th utility. *Future Generation Computer Systems*, *25*(6), 599–616.

Costa, P. M. A. C. (2013). Evaluating Cloud Services using Multicriteria Decision Analysis. Retrieved from https://fenix.tecnico.ulisboa.pt/downloadFile/395145548440/dissertacao.pdf

Dialogic Corporation. (2010). Introduction to Cloud Computing. Retrieved from http://www.dialogic.com/~/media/products/docs/whitepapers/12023-cloud-computing-wp.pdf

Hauck, M., Huber, M., Klems, M., Kounev, S., Müller-Quade, J., Pretschner, A., & Tai, S. (2010). Challenges and opportunities of cloud computing. *Karlsruhe Reports in Informatics, 19*. Retrieved from http://digbib.ubka.uni-karlsruhe.de/volltexte/documents/1978786

KPMG International. (2011). The Cloud Changing the Business Ecosystem. Retrieved from http://www.kpmg.com/IN/en/IssuesAndInsights/ThoughtLeadership/The_Cloud_Changing_the_Business_Ecosystem.pdf

Lee, C. & Nickerson, B. (2011). Cloud computing: Vendor selection and asset protection. Deloitte. Retrieved from http://www.deloitte.com/assets/Dcom-UnitedStates/Local%20Assets/Documents/AERS/us_aers_foct_Protecting_your_investment_08292011.pdf

Marinescu, D. C. (2013). *Cloud Computing: Theory and Practice*. Boston: Morgan Kaufmann.

Ngeru, J. (2012). *Multi-criteria decision analysis framework in the selection of an enterprise integration (EI) approach that best satisfies organizational requirements*. Doctorate Dissertation, Morgan State University. Retrieved from http://gradworks.umi.com/35/16/3516883.html

Ngeru, J., Bardhan T., & Pitts, R. (2011). A Delphi-Multi-Criteria Decision Making Approach in the Selection of an Enterprise-Wide Integration Strategy. In *Proceedings of the Second International Conference on Information Management and Evaluation*. Academic Conferences.

Ngeru, J., Bardhan, T., Hargrove, K., & David, D. (2009). Developing Enterprise Integration Strategy Using an AHP approach. *Journal of Management and Engineering Integration*, *2*(1).

Qu, L., Wang, Y., & Orgun, M. A. (2013). Cloud service selection based on the aggregation of user feedback and quantitative performance assessment. In *Services Computing (SCC), 2013 IEEE International Conference on* (pp. 152–159). IEEE. Retrieved from http://ieeexplore.ieee.org/xpls/abs_all.jsp?arnumber=6649690

Saaty, T. L. (1980). *The Analytic Hierarchy Process, Planning, Piority Setting, Resource Allocation*. New York: McGraw-Hill.

Shawky, D. M. (2013). A cost-effective approach for hybrid migration to the cloud. *International Journal of Computer and Information Technology*, *2*(1), 57–63.

Song, Z. (2013). A decision support system for application migration to the Cloud. Retrieved from http://elib.uni-stuttgart.de/opus/volltexte/2013/8262/

Sureshchandar, G. S. & Leisten, R. (2006). A framework for evaluating the criticality of software metrics: an analytic hierarchy process (AHP) approach. *Measuring Business Excellence*, *10*(4), 22–33. doi:10.1108/13683040610719254

Taleai Mohammad, M. A. (2008). Using Delphi-AHP Method to Survey Major Factors Causing Urban Plan Implementation Failure. *Journal of Applied Sciences*. doi:10.3923/jas.2008.2746.2751

Tavana, M., Kennedy, D. T., Rappaport, J., & Ugras, Y. J. (1993). *An AHP-Delphi Group Decision Support System Applied to Conflict Resolution in Hiring Decisions* (SSRN Scholarly Paper No. ID 1373854). Rochester, NY: Social Science Research Network. Retrieved from http://papers.ssrn.com/abstract=1373854

Ustinovichius, L., Zavadkas, E. K., & Podvezko, V. (2007). Application of a quantitative multiple criteria decision making (MCDM-1) approach to the analysis of investments in construction. *Control and Cybernetics*, 36(1), 251–268.

Whaiduzzaman, M., Gani, A., Anuar, N. B., Shiraz, M., Haque, M. N., & Haque, I. T. (2014). Cloud Service Selection Using Multicriteria Decision Analysis. *The Scientific World Journal*, *2014*, 1–10. doi:10.1155/2014/459375

Zardari, S., Bahsoon, R., & Ekart, A. (2014). Cloud Adoption: Prioritizing Obstacles and Obstacles Resolution Tactics Using AHP. In *Requirements Engineering Track, The 29th ACM Symposium On Applied Computing, Gyeongju, Korea*. Retrieved from http://www.cs.bham.ac.uk/~sxz845/Obstacles-AHP.pdf

Zhang, M., Ranjan, R., Haller, A., Georgakopoulos, D., & Strazdins, P. (2012). Investigating decision support techniques for automating cloud service selection. In *Cloud Computing Technology and Science (CloudCom), 2012 IEEE 4th International Conference on* (pp. 759–764). IEEE. Retrieved from http://ieeexplore.ieee.org/xpls/abs_all.jsp?arnumber=6427501

Zhang, Q., Cheng, L., & Boutaba, R. (2010). Cloud computing: state-of-the-art and research challenges. *Journal of Internet Services and Applications*, 1(1), 7–18. doi:10.1007/s13174-010-0007-6