Cloud Readiness Assessment Framework and Recommendation System

Fasil Alemeye
HiLCoE, Computer Science Programme, Ethiopia
fasilo@outlook.com

Fekade Getahun
HiLCoE, Ethiopia
Department of Computer Science, Addis Ababa University, Ethiopia
fekade.getahun@aau.edu.et

Abstract

Cloud computing is one of the fastest growing technologies. For developing countries like Ethiopia which has a growing ICT, cloud computing is an attractive choice to adopt. However, the adoption of such a technology should be planned ahead of time taking into consideration the various factors that make adoption successful.

The main objective of this research is to propose a cloud readiness assessment framework and an expert system that assesses cloud readiness and recommend which cloud deployment and service model to adopt.

The research is grounded by well-studied technological innovation adoption theories: Technology Organization Environment framework (TOE), Diffusion of Innovation (DOI) and Technology Acceptance Model (TAM). Based on these theoretical foundations, a new cloud readiness framework is proposed. A survey is designed based on the framework; using this survey an initial dataset is generated and expanded using synthetic data generator.

The expert system relies on predictive modelling for assessing cloud readiness. So, using Weka machine learning platform, J48 decision tree algorithm is experimented using various settings, to train and obtain acceptable model accuracy. Training is performed on the original dataset and synthetically generated dataset. The best obtained model accuracy is 75% with the original dataset.

Keywords: Cloud Readiness Assessment; Cloud Computing Adoption; Cloud Computing Recommendation System; Predictive Modelling in Cloud Computing; Cloud Assessment Framework

1. Introduction

Cloud computing comes with a lot of promises and associated advantages. This makes it an attractive choice for adoption for many organizations. However, with the introduction of new technology comes the challenge of readiness assessment, adoption and implementation. Thus, an organization that wants to adopt a technological innovation must plan strategically. Otherwise, the adoption of a technology like cloud computing rather than benefiting the organization might introduce problems like violation of policies, service latency and security issues.

This research addresses the following research questions:

- What are the factors that affect organizations' cloud readiness?
- What are the factors that affect organizations' cloud adoption?

The objective of this research is to provide a cloud readiness assessment framework and an expert system. The expert system provides cloud readiness assessment and recommends which cloud deployment and service model to adopt.

In order to accomplish the stated objectives the research follows a design science research methodology [1].

Twenty nine organizations in Ethiopia are selected for the survey. Survey quality assurance and pre-processing is conducted. The unit of analysis for this research is organizations and individuals that exist within them.

The survey provides us with the initial dataset. The questionnaire in the survey is designed so that it aligns to the independent variables identified.

The responses from the questionnaire are automatically collected as the user clicks submit and are stored as a spreadsheet format directly from Google docs. The spreadsheet is then pre-processed.

Several tools exist to generate synthetic data. In this research Benerator tool is used, Benerator is a tool used in [2] for creating realistic and valid high volume synthetic/test data. In this research it is used to generate 1,000 synthetic data from the initial dataset collected.

In Weka a standard way of representing datasets is in ARFF file format. An ARFF (Attribute-Relation File Format) file is an ASCII text file that describes a list of instances sharing a set of attributes. Accordingly the original dataset as well as the synthetically generated dataset are formatted to ARFF format.

2. Related Work

In this section, works related to this research are discussed. The review focuses on cloud readiness factor, cloud services model and cloud deployment.

2.1 Cloud Readiness Assessment and Recommendation

In this work, existing works are assessed using theoretical foundation, real world applicability, support for automated decision making, inclusion of relevant factors, vendor neutrality, ease of use, scalability and level of recommendation they provide and predictive analytics as evaluation lens. However, factors are restricted only to IaaS, SaaS, Private cloud and public cloud readiness factors.

In [3], Loebbecke *et al*. introduced a magic matrices method composed of three steps – IT service identification, screening and categorization. The method is implemented by a large multi-national automotive company - Continental AG - for auto cloud readiness assessment. Its service assessment is too tedious and not easy to manage when the number of services is large. The screening step uses seven criteria. The categorization is restricted only to likely cloud ready, not yet cloud ready and unlikely to be assessed as cloud ready in the next years. This work lacks scalability, relevant criteria, literature foundation, ease of use and it provides poor recommendation.

Federal CIO: Cloud Selection Toolkit is a project [4], for the United States government agencies to assist strategic readiness assessment and adoption of cloud technology. The toolkit contains 4 main steps: data gathering, cloud readiness assessment, vendor selection and change and risk management. The work is based on several criteria to recommend a cloud solution and specific cloud type for the assessed organization. However, the work did not consider perceived usefulness and simplicity of usage assessment criteria, and there is no automation support.

In [5], Trivedi introduced a TOE based cloud readiness assessment approach. The author used nine dimensions categorized into three context factors - organizational (executive support, business case and budget, application rationalization and modernization), technological (standardization, service level definition, process analysis) and environmental (vendor readiness). However, the work lacks automation, recommendation and also real world applicability.

Cisco and Redhat developed cloud readiness assessment tool. The Redhat's cloud readiness self-assessment tool [6] evaluates an organization's readiness for cloud computing using two axes: organizational and technology readiness. It uses 20 questions related to an organizational strategy, process, IT architecture, and governance and people to assess an organization's cloud readiness. It then compares the result with the results of over 120 enterprise organizations surveyed for their cloud computing readiness. Cisco's Cloud readiness assessment tool [7] collects input from users using four dimensions - business, technology, people and processes. However, the tool does not consider

business aspect of an organization. Both Cisco's and Redhat's cloud assessment tools do not have documented theoretical foundation. Additionally, most vendor tools try to lure a potential client to their own product lines.

2.2 Cloud Service and Cloud Deployment Model Readiness

In this paper, the cloud service model assessment is restricted to only IaaS and SaaS. According to Cisco [8] SLAs, data portability, long-term costs, user management, and security are the major factors for IaaS migration. However, it fails to consider important factors such as technological, organizational and environmental aspects. Business constraints are limiting the ability to meet IT service delivery needs.

Benlian *et al*. in [9] used transaction cost theory, the resource-based view, and the theory of planned behavior as factors to assess SaaS adoption at the application level. They surveyed 297 firms in Germany and documented social influence, attitude toward SaaS adoption, adoption uncertainty, and strategic value as the strongest and most consistent drivers independent of application type and firm size.

Madisha and Belle [10] studied factors influencing SaaS adoption focusing on South Africa as an emerging economy. The dominant SaaS adoption factors are: awareness, security and privacy concerns, Internet access costs, Internet bandwidth and organizational resources.

Forrester's "SaaS Capabilities Maturity Assessment" [11] helps companies assess whether SaaS is a strong or weak fit, identify readiness to adopt SaaS for a specific purchase, and address hurdles to SaaS success. The maturity assessment contains five main parts which are: 1) the solution category is a good candidate for software-as-a-service; 2) the SaaS solution has the requisite technical capabilities to support the business requirement; 3) an organization has development skills suitable for SaaS or not; 4) an organization has an appropriate solution governance process to capitalize on the benefits of SaaS or not; and 5) SaaS purchasing processes are sound or not. Again although these studies provided the major factors that affect SaaS adoption process, they fail short on providing an automated real world application that leverages their study findings. In addition, studies in [12, 13, 14] provide the major factors that affect SaaS and IaaS adoption process, but they fail short on providing a real world application that leverages their study findings.

In the context of cloud deployment, public or private, several researches are conducted. Some of the factors that influence adopting public cloud are simplicity and efficiency, low cost, reduced time of maintenance, and no contracts or long time commitment. In cases when an application is traffic intensive and communicates with applications or consumes resource in other data centers, migration to a public cloud is not recommended. In addition, for applications dependent on the legacy protocol and/or strict data security and compliance requirements public clouds are not the ideal choice [8, 15]. The main factors for private cloud adoption are the need for greater control, more security, high performance, deeper compliance, customizable, and applications dependent on the legacy protocol.

3. Cloud Readiness Assessment Framework

The cloud readiness assessment framework proposed in this paper is based on the three theoretical foundations on technology adoption discussed earlier. Based on these theoretical foundations, a new cloud readiness assessment framework which combines TAM, TOE and DOI is proposed. Similar integration approach has been exhibited by Awa *et al*. in [16]. They integrated TOE and TAM for E-Commerce adoption by small and medium enterprises. In another work [12] DOI and TOE are used as a conceptual model to study factors influencing the adoption of cloud computing by small and medium-size enterprises. Our research is different in that, it utilizes three of them leveraging their advantage as a whole.

Such approach is never utilized in cloud computing readiness assessment.

The units of analysis used in this research are mainly organizations and individuals within them following the work in [12]. The assumption is that, through standard IT service management practices like ITIL, the individual qualities like perceived ease of use is documented and can be responded by a representative of the organization. Additionally, if such practice is not in place, a survey can be taken beforehand to assess such individual qualities.

The proposed cloud readiness model is shown in Figure 1. It is composed of three layers each representing the theoretical foundations.

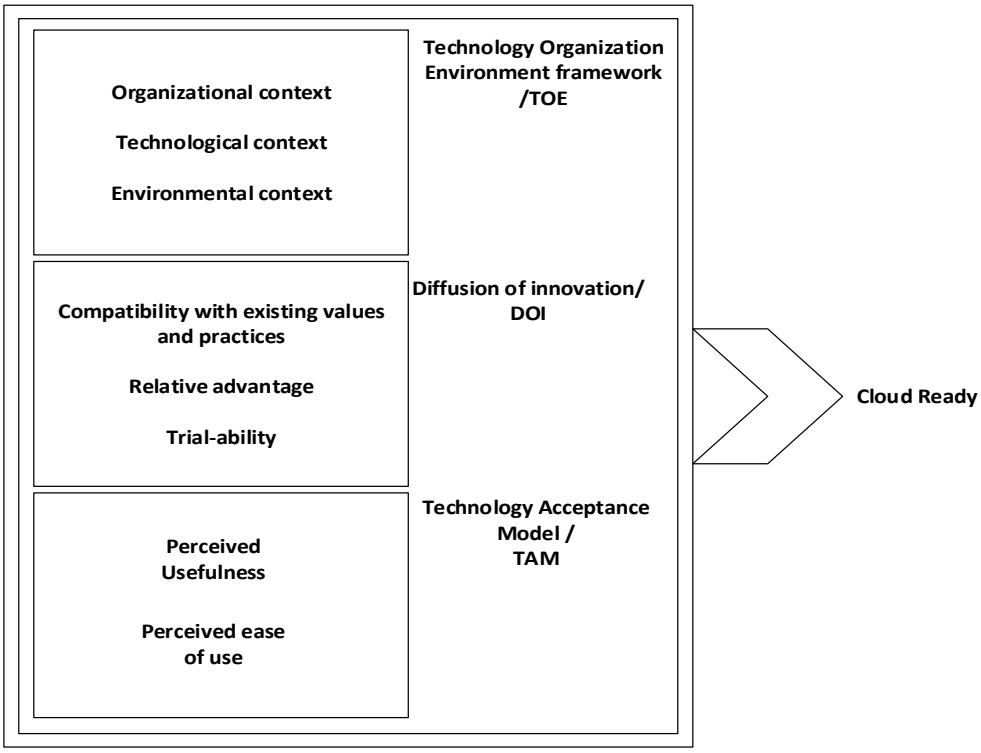

Figure 1: Cloud Readiness Assessment Framework

The first layer (bottom of Figure 1) relies on TAM's two core factors, i.e., perceived usefulness and perceived ease of use that influence behavioral intention to use a system.

The second layer (middle on Figure 1) relies on DOI. DOI theory identifies five qualities that determine adoption of new products. These are: relative advantage, compatibility with existing values and practices, simplicity and ease of use, trial-ability and observable result [17]. Only three qualities are adopted, because perceived ease of use exists in both DOI and TAM. Observable result is fused in trial-ability. These theories collectively assess whether an organization is cloud ready or not.

The third layer (top on Figure 1) relies on TOE framework. In TOE, there are three contexts: organizational, technological and environmental. In the organizational context, we have used two factors - executive support, and business case and budget. In the technological context, we used technological readiness and network connectivity. In the environmental context, we used competitive pressure.

In this work, we mainly used popular factors that are used as factors in different related researches.

Thus in this work, we used 12 readiness factors in order to determine organizational cloud readiness (CR). The attributes are from TAM Perceived usefulness (PU), Perceived Ease of use (PE), Relative Advantage reside (RA), from DOI Trial-ability and observable Result (TO), Compatibility with existing values and practices (CE), and from TOE Executive support (ES), Business case and Budget (BB), Technological Readiness Number of Servers (TRNS), Technological Readiness Server Age (TRSA),

Technological Readiness Virtualization (TRVI), Network connectivity (CO), and Competitive edge (CA). These attributes are the foundation to the predictive model built using J48 supervised machine learning algorithm for cloud readiness.

To access cloud service and deployment model readiness assessment the following factors are considered: High Scalability and Long Term cost for IaaS readiness [8], SaaS readiness, Adoption uncertainty and data portability [8, 11] for SaaS readiness, Data security and management for Public cloud readiness [8, 15]. Compliance and governance, need for high compliance, government regulation, Application dependency, High Reliability and control, High Performance need: An organization's demand for high performance, and Skilled human resource for Private cloud readiness [5, 8, 14, 15].

These factors are used by the expert system to recommend the appropriate deployment and service model to adopt.

4. Survey Design and Finding

In order to gather relevant data, we have prepared an online questionnaire that contains the different factors described in the previous section. The questionnaire is prepared using Google forms and used to gather data from organizations about their cloud adoption and readiness.

We communicated IT managers of 29 cloud aware organizations in Addis Ababa, Ethiopia, and sent the URL of the questionnaire. These organizations are selected randomly. The sample is small because the number of cloud aware organizations in Ethiopia is very few.

Out of the 29 participants in the survey, 3 responses were removed in the preprocessing phase. The survey questions and responses which are used for prediction are:

1. Have you adopted cloud computing? Where said 55% yes and 45% said no.
2. PU - Do you think cloud computing is useful technology to adopt? Where 93% said yes and 7 % said no.
3. PE - Do you think cloud computing is complex technology to adopt? 38% yes and 62% no.
4. RA - Do you think cloud computing is more advantageous than traditional IT deployment? 93% yes and 7% no.
5. TO - Do you think trying or evaluating cloud computing first is important before adopting it? 100% yes.
6. CE - Do you think cloud computing is compatible with your company's existing IT infrastructure and ITSM? 66% yes and 34% no.
7. ES - Is there executive or higher management support and knowledge for any cloud related initiative? 45% yes, 11% no and 17% other.
8. BB - Have you developed business justification for implementing cloud projects? 34% yes, 55% no and 10% other.
9. TRNS - How many Servers do you have? <10: 34%, 10 – 100: 62%, 500 – 1000: 3%.
10. TRSA - What is an average age of your servers? <1 year: 7%, 2-5 years: 66%, 5+ years: 28%.
11. TRVI - How many of your servers are virtualized? With a scale of 1 to 5 where 5 representing full virtualized environment. The responses were 28% said 1, 21% said 2, 28% said 3, 10% said 4 and 14% said 5.
12. CO - What is your connection bandwidth to the Internet? Where 7% said less than 2 Mbps, 48% said less than 2 Mbps, 7% said 11 - 20 Mbps, 24% said 20+ Mbps and 14% said other.
13. CA - Do you think adoption of cloud computing will give you an edge to your competitors? 76 % yes, 21% no.

Important information is extracted from the response which is used as initial dataset, that was later synthetically expanded.

5. Expert System Design

An expert system is an automated reasoning system that attempts to mimic the performance of a

human expert [18]. In this work, an expert system is developed to integrate the machine learning – predictive with cloud readiness knowledge base developed through questionnaire.

Our expert system is developed using Asp.NET and consists of three layers, i.e., presentation, middleware and machine learning platform layer.

The presentation layer is responsible to accept input from users and pass it to the prediction subsystem and the recommendation subsystem. Accordingly, the data needed for prediction will go through the middleware and to the machine learning platform. The machine learning platform is Weka that classifies the data and returns the result to the middleware. The middleware communicates the result to the presentation layer which finally displays the result to the user. In addition, the expert system has a component that updates the knowledge base (i.e., training dataset) with the new instance.

6. Experimentation

In this work, in order to identify classification models that represent cloud readiness, a set of experiments are conducted using the original dataset and syntactically generated dataset. The dataset is divided into training and dataset. The following shows the result of the experimentation.

- Using only the original dataset, it classifies 75%.
- Using cross-validation on the original dataset. It classifies 65.3846%.
- Using only synthetically generated dataset, it classifies 71.9064%.

7. Discussion and Conclusion

This paper addresses two research questions: what are the factors that affect organizational cloud readiness? and what are the factors that affect organizational cloud adoption?.

After carefully reviewing literature and identifying gaps in previous works, a cloud readiness framework is proposed. The framework is grounded by three theories, which makes it unique from related works. This framework is also used as a foundation for designing a survey.

The developed expert system combines cloud readiness prediction and recommendation, and provides an automated solution to the end user. The proposed theoretical framework is used as a foundation for predictive analytics. The expert system provides recommendation related to the appropriate cloud deployment and cloud service model. Most of the works reviewed lacked such an integrated and automated solution.

In general, this work tried to fill gaps identified in previous works in terms of theoretical foundation, real world applicability, aiding automated decision making, inclusion of relevant factors, vendor neutrality, ease of use, scalability and level of recommendation. Additionally, the use of predictive analytics which is new in this work is provided.

8. Future Work

This research proposed a framework for cloud readiness assessment and an expert system. The expert system provides cloud readiness assessment based on predictive analytics and recommends which cloud deployment and service model to adopt. Although an attempt is made to make the work as extensive as possible, due to many factors, there are missing links that need to be addressed by other researches.

The framework itself should be studied and its application should be attested in other countries. With more studies its advantages and applications can become apparent and any overlooked pitfalls will be identified. For instance, Internet connectivity is a significant factor in developing countries, but it is less relevant in developed countries.

In the future, we plan to implement the machine learning algorithm directly in the expert system without using the middleware itself as it improves the performance of the system.

References

[1] Hevner, Alan, Chatterjee, Samir, "Design Science Research in Information Systems Theory and Practice," Springer Integrated Series in Information Systems, Vol. 22, 2010.

[2] Vanessa Ayala-Rivera, Patrick McDonagh, Thomas Cerqueus, and Liam Murphy, "Synthetic Data Generation using Benerator Tool," University College Dublin, Dublin, October 29, 2013.

[3] Claudia Loebbecke, Bernhard Thomas, and Thomas Ullrich, "Assessing Cloud Readiness: Introducing the Magic Matrices Method Used by Continental AG," Managing the Transfer and Diffusion of IT, IFIP Advances in Information and Communication Technology, Vol. 366, pp. 270-281, 2011.

[4] Chris Radich, Dana Christiansen, Doyle Zhang, and India Donald, "Federal CIO: Cloud Selection Toolkit," 2011. Available at: http://www.governmentciomagazine.com/sites/default/files/Cloud%20Selection%20Toolkit%20_MPTM%20632_Summer2011_Final (Group%20_1).pdf, Last accessed 20 May 2014.

[5] Hrishikesh Trivedi, "Cloud Adoption Model for Governments and Large Enterprises," Unpublished MSc Thesis, Massachusetts Institute of Technology, Massachusetts, 2013.

[6] Redhat, "Cloud Readiness Assessment", Available at: https://engage.redhat.com/forms/cloud-readiness-assessment, Last accessed on 5 February 2014.

[7] Cisco Systems, "Cisco Cloud Assessment Tool," Available at: http://www.ciscowebtools.com/cloud, Accessed on 5 February 2014.

[8] Cisco Systems, "Planning the Migration of Enterprise "Applications to the Cloud", Available at: https://www.cisco.com/en/US/services/ps2961/ps10364/ps10370/ps11104/Migration_of_Enterprise_Apps_to_Cloud_White_Paper.pdf, Last accessed on 5 February 2014.

[9] Alexander Benlian, Thomas Hess, and Peter Buxmann, "Drivers of SaaS Adoption - An Empirical Study of Different Application Types," Business & Information Systems Engineering, Vol. 1, No. 5, pp. 357-369, 2009.

[10] M. Madisha and J.P. Van Belle, "Factors Influencing SaaS Adoption by Small South African Organizations," in The 11th Annual Conference on World Wide Web Applications, Durban, South Africa.

[11] liz Herbert, "Forrester - SaaS Capabilities Maturity Assessment", Available at: http://media.cms.bmc.com/documents/Forrester_SaaS_Capabilities_Maturitity_Assessment+(2).pdf, Last accessed 5 February 2014.

[12] Tehrani, Shima Ramezani, "Factors Influencing the Adoption of Cloud Computing by Small and Medium-Sized Enterprises (SMEs)", Unpublished MA Thesis, Ryerson University, Management of Technology and Innovation, 2013.

[13] Franco Di Biase, "Legacy to Cloud Migration: Assessing the Cloud Readiness of Legacy Software Systems', Northwestern Switzerland: Unpublished MS. Thesis, University of Applied Sciences of Northwestern Switzerland, 2013.

[14] Lorraine Morgan and Kieran Conboy, "Factors Affecting the Adoption of Cloud Computing: An Exploratory Study," in 21st European Conference on Information Systems, ECIS, Utrecht, Netherlands, 2013.

[15] Aerohive Networks, Inc, "Public or Private Cloud: The Choice is yours," Available at: http://www.aerohive.com/pdfs/Aerohive-Whitepaper-Public-or-Private-Cloud.pdf, Last accessed on 5 February 2014.

[16] Hart O. Awa, Ojiabo Ukoha and Bartholomew C. Emecheta, "Integrating TAM and TOE Frameworks and Expanding their Characteristic Constructs for E-Commerce Adoption by SMEs," in Proceedings of Informing Science & IT Education Conference, Montréal, Canadá, 2012.

[17] Rogers, Everett M., "Diffusion of Innovations", New York Free Press, 2003.

[18] Wayne Goddard, "Artificial Intelligence with heavy emphasis on Game Players and Puzzle Solvers," Available at: http://people.cs.clemson.edu/~goddard/texts/cpsc810/chapA7.pdf., Last accessed on 15 March 2014.