Fuzzy MCDM Approach for Building Private Cloud Medical Records

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***Abstract* —This paper aims to introduce the application of Fuzzy MCDM approach to tackle the selection issue in building private cloud medical records. Vast amount medical records currently require a solution to build cloud data storage. Cloud based data storage is currently required to deal with continuous demand of electronic medical records in particular during covid 19. Private cloud data center is proposed to overcome the issue of storing daily medical records from various sources. The study proposes a Fuzzy MCDM model based on the Analytic Hierarchy Process (AHP) in choosing the best open source cloud data storage for establishing private cloud medical records. There are many perspectives to be compromised during the selection process of several open source solutions and all pairwise comparison should meet maximum inconsistecy rate of 0.1. It is finally concluded that OwnCloud is the most suitable open source solution for solving the given problem.**

Key words -. Medical Record, Cloud Computing, Decision Making, Fuzzy AHP, Open Source.

I. INTRODUCTION

Since the era of the Covid 19 pandemic, the need for medical record storage media has grown rapidly. Indonesia, which is included in the list of countries most affected by Covid 19, has felt the surge in medical record data in the last two years. Doctors and other health staff are not only required to provide the best health services to the community during this pandemic but are also forced to produce integrated and centralized health service document reports. This need cannot be met by traditional medical records information systems which are generally still applied in all hospitals and public health centers in Indonesia [1].

This study tries to bridge this gap by proposing the use of cloud computing technology to overcome the surge in medical records. It is projected that with cloud technology-based solutions, health services are centered on accessing medical records anytime and anywhere. The use of the cloud computing paradigm in healthcare facilitates the sharing and integration of medical records [2]. However, to choose the cloud technology option, a MultiCriteria Decision Making approach is needed so that the resulting decisions actually involve a number of aspects in making these medical records decisions.

Considering the advantages of cloud computing and the difficulties in making decision incorporating different views, we aim to propose a Fuzzy Multi Criteria Decision Making (MCDM) based on the Analytic Hierarchy Process (FAHP) approach to deal with the issue on how to choose among many open source cloud storage for developing private cloud medical records.

The paper is structured within five sections. Section 2 presents theoretical concepts about new cloud technology and open source solution for cloud storage. Next, methodology being used is described in section 3. Details of analysis and results are found in the next section. Finally, section 5 concludes the findings of this research.

II. LITERATURE REVIEW

Cloud storage refers to the storage of data using cloud computing technologies. Due to its four unique characteristics, currently cloud computing commonly ap-plied in many organizations, such as government, universities and business.

On demand aspect is the first characteristic of cloud computing. Anytime more CPU, storage or network demanded, users automatically will obtained such services without direct allocation by the service provider [3].

Second characteristic is resource pooling that enables users to obtain combina-tion of various cloud resources although they have different requirements in sim-ple way [3][4].

The third one namely rapid elasticity is the uniqueness of cloud computing that enable users to scale up services or scale down according to their needs.

The final aspect of cloud computing is known as calculated services. This helps cloud providers to know exactly how many programs or facilities are used by individual users or shared by multiple users [5].

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Cloud computing also unique in terms of service model it applies. Three ser-vice model known as Software as a Service (SaaS), Platform as a Service (PaaS), and Infrastructure as a Service (IaaS)

In addition, fundamental cloud computing is also unique from its deployment model. Basically, there are three types of cloud computing model, Public, Private and Hybrid.

Cloud storage system as addressed in this study specifically deals with de-ployment model [8]. Cloud storage is a combination of IaaS and SaaS. It is con-sidered as cloud infrastructure, and SaaS as it relies on particular applications to make users able to store their digital data on the cloud [6].

Currently, cloud storage solution might be found as both open and closed source basis. Considering low cost in mind, we only discuss open source in this re-view, since this is the key focus to be mentioned. Three open source cloud storage tools are OwnCloud [7], Seafile [8], and Cozy [9]. The way to properly choose these open source cloud storage will be approached using Fuzzy Analytic Hierar-chy Process (FAHP) methodology mentioned below.

III. METHODOLOGY

As the study falls into multi criteria decision making problem, Analytic Hierarchy Method (AHP) in combination with Fuzzy Set Theory is implemented. AHP is the most common MCDM methodology used in academic and industry case study [10][11][12] to address problems containing various points of view, different crite-ria that often clash with each other, with a variety of alternatives to be preferred or selected[12].

The AHP based hierarchy for the given problem is presented in figure 1, con-sidering five aspects namely response time, accuracy, stability, security, and community support.

In many studies, AHP has been widely applied in many success practical cas-es that involving multiple aspects, point of view both qualitative and quantitative means [13]. According to Saaty [13] AHP is applied within the following steps:

- Establish the objective that needs to be addressed.
- Develop a hierarchy of decision-making elements.

In the simplest, it consists of three layers, the objective or sometimes called goal, then the point of view and finally the alternatives.

- Perform pair-wise comparison for all layers of requirements and alterna-tives.
- Calculate the degree of accuracy level to ensure that decisions are con-sistent.
- Calculate the proportional weights of the components of the judgment.
- Integrate all hierarchical weights to get the final rank from the highest to the lowest ones..

In addition to advancing AHP, Fuzzy set theory which is based on the ration-ality of ambiguity due to fuzziness or ambiguity usually implemented in integra-tive way [12].

In the field of Multi Criteria Decision Making, fuzzy set theory has given a significant contribution by accepting uncertainty and inconsistent judgment as a nature of human decision making [12][14].

Fuzzy set is determined by a membership function whose membership is defined by Lower, Medium and Upper numbers. The membership function of M=(l,m,u) is given by

$$\mu(x)=\begin{cases}\dfrac{x-l}{m-l} & if\ l\le x\le m\\ \dfrac{u-x}{u-m} & if\ m\le x\le u\\ 0 & if\quad x<l\ or\ x>u\end{cases} \qquad \text{.....(1)}$$

These fuzzy numbers may be calculated by means of a formula, either by us-ing them explicitly on the basis of the decision-maker's interpretation or by taking them from linguistic variables on a verbal scale.

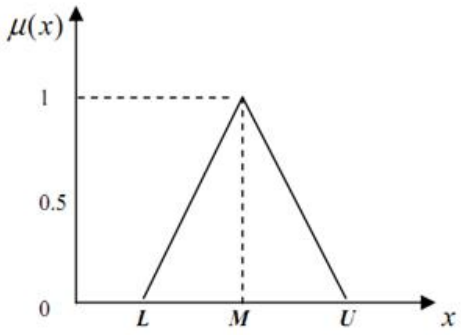

Fig. 1. Triangular fuzzy numbers

Table 1 shows the linguistic variables and their associated fuzzy scales as well as reciprocal scales which will be used in the calculation processes using fuzzy set theory in conjunction with the Analytic Hierarchy Process.

Table 1. Fuzzy linguistics variable.

Linguistic Variable	*Fuzzy Scale*	*Reciprocal Scale*
Equally Important	(0.5, 0.5, 0.5)	(0.5, 0.5, 0.5)
Slightly Important	(0.55, 0.6, 0.65)	(0.35, 0.4, 0.45)
Important	(0.65, 0.7, 0.75)	(0.25, 0.3, 0.35)
Very Important	(0.75, 0.8, 0.85)	(0.15, 0.2, 0.25)
Absolutely Important	(0.85, 0.9, 0.9)	(0.1, 0.1, 0.15)

In terms of analysis stages, the same procedure of classical AHP steps is ap-plied except the crisp numbers in which we use fuzzy numbers as represented in table 1.

IV. Results And Discussion

In structuring decision hierarchy, we follow approach proposed in [12]. He sum-marized several factors significantly contribute to the successful adoption of cloud computing technology, whether in the form of SaaS, IaaS or PaaS. Similar approach was adopted in this paper by developing a new Cloud Adopting System for Decision Making of Open Source Cloud Storage.

It suggests five fundamental aspects to consider in the adoption of any cloud computing technology [12]. The aspects are response time, accuracy, stability, se-curity, and community support. These aspects are carefully and properly consid-ered in shaping the selection process of cloud based storage system. For further description on each of these aspects, readers may refer them in more details in [12][13].

Figure 2 clearly shows the decision hierarchy which is structured within three levels. The decision hierarchy is organized properly by following structure based on the Analytic Hierarchy Process. Then with the employment of the fuzzy trian-gular numbers, we could make the survey understandable by employing linguistic variables.

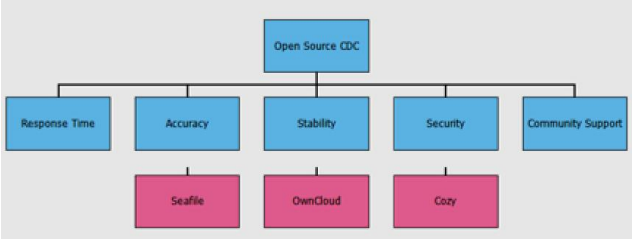

Fig. 2. The decision hierarchy

The first pairwise comparison is applied to the five aspects with respect to the goal. As can be seen in figure 3, weights for response time, accuracy, stability, se-curity and community support are accounted for 0.178, 0.198, 0.178, 0.223 and 0.223 respectively. This clearly shows that the highest aspect to be considered is both security and community support.

Then the pairwise comparison is applied to the three alternatives with respect to each of the five aspects. Figure 4 shows the weights for Seafile, OwnCloud and Cozy with respect to response time are accounted for 0.345, 0.497 and 0.158 re-spectively. This clearly shows that OwnCloud is the best alternative from response time point of view.

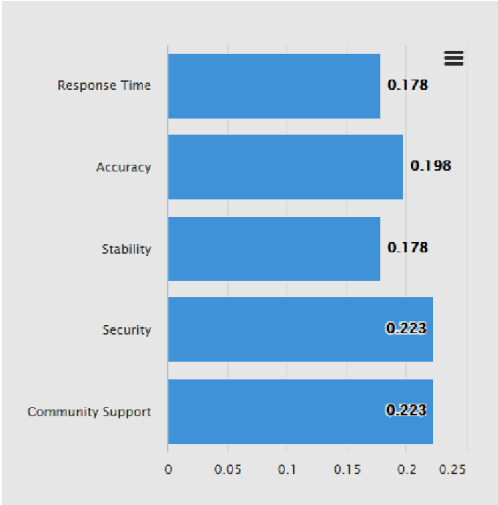

Fig. 3. Priorities with respect to goal

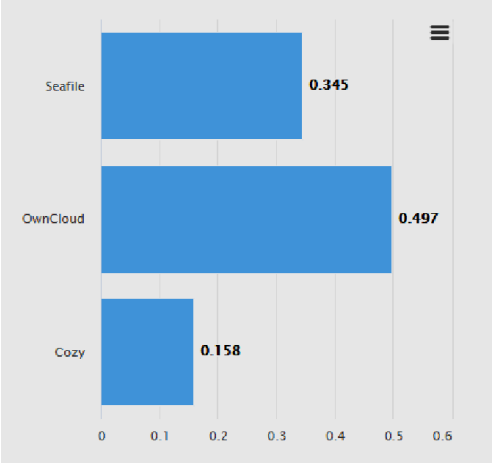

Fig. 4. Priorities with respect to Response Time

Next pairwise comparison is applied again to the three alternatives (Seafile, OwnCloud and Cozy) with respect to accuracy aspect. The results are the same for all three alternatives by 0.333. This clearly shows that Seafile, OwnCloud and Cozy are considered equal from accuracy point of view (see figure 5).

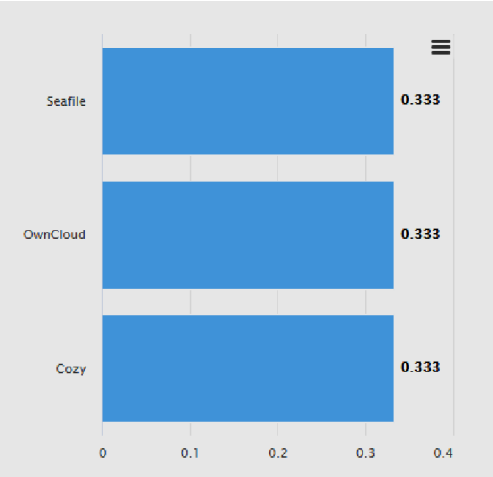

Fig. 5. Priorities with respect to Accuracy

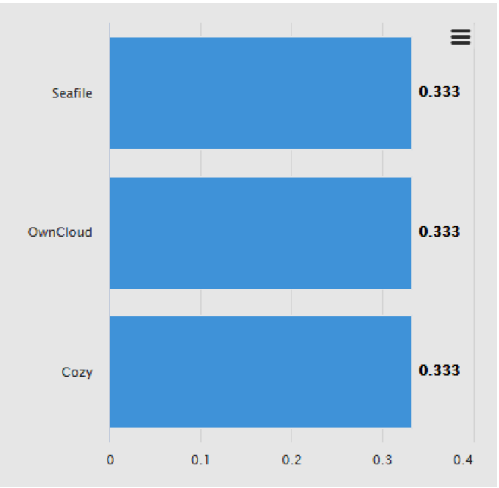

Fig. 6. Priorities with respect to Stability

The same results are presented in figure 6 where pairwise comparison is ap-plied to Seafile, OwnCloud and Cozy as alternatives with respect to stability aspects in which all three alternatives has the same weight of 0.333. This means from stability point of view, Seafile, OwnCloud and Cozy are considered equal.

Figure 7 shows the results of pairwise comparison of Seafile, OwnCloud and Cozy with respect to security aspect. Cozy is selected as the highest weight of 0.566 followed by OwnCloud of 0.434 and Seafile of 0.

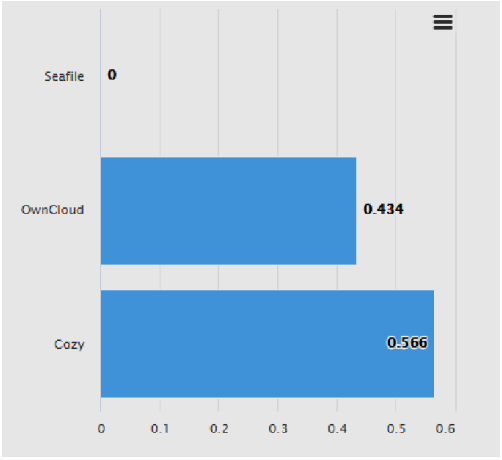

Fig. 7. Priorities with respect to Security

The last pairwise comparison of Seafile, OwnCloud and Cozy is applied with respect to the last aspect of community support. As depicted in figure 8, Own-Cloud received significant weight of 0.958, while Cozy only 0.042 and again Seafile is 0.

Finally, the whole results are aggregated to obtain the final weight of all alter-natives as described in table 1. It is clearly concluded that OwnCloud is chosen as the most suitable open source cloud data storage solution for the development of electronic learning data center based on cloud technology.

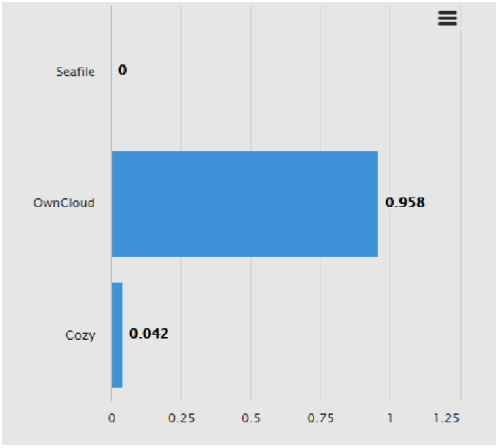

Fig. 8. Priorities with respect to Community Support

Table 2. Final result

Rank	*Open Source Cloud*	*Weight*
1	OwnCloud	0.524
2	Cozy	0.288
3	SeaFile	0.186

It is finally obtained that the application of Fuzzy AHP method has chosen OwnCloud as the most applicable one among others. The selection of OwnCloud is mainly because its large community supports from its users all around the world that has been existing earlier than other alternative open source cloud storages. Such community support is believed as effective source for in-house developer in dealing with improving features and facilities of OwnCloud.

In terms of security aspect, although OwnCloud weight is below Cozy since Cozy offers better security mechanisms, the limitation might be tackled by open source third party as suggested by OwnCloud community. As a result, OwnCloud still dominates other options in many aspects therefore it is chosen as the best one to be deployed in this study.

Through this study, fuzzy AHP methodology has been applicable to support the selection process by tackling vagueness of human decision making process [14] such as in building cloud based medical records.

The novelty of our approach is unique in terms of methodology development and object being observed. Previous related studies found that similar problem focused on selection of cloud providers [15], service selection of cloud [16] or more recently cloud services selection in hybrid cloud [17] or based on different methodology such as market mechanism [18] particular consensus mechanism [19]. Hence, the application of Fuzzy AHP in selecting the best open source cloud storage is a new approach in the area.

V. Conclusion

The issue of how to make selection among several candidates of open source storage to develop private cloud medical records has been addressed in this study. Fuzzy MCDM based on AHP methodology was applied to guide the selection process to accommodate vagueness in decision making process. The decision hierarchy consists of three layers (goal-aspect-alternative), in which the last layer (alternative layer) represents the three candidates of open source cloud storage namely OwnCloud, Cozy and Seafile to be selected.

Considering five aspects of response time, accuracy, stability, security and community support (aspect layer), Owncloud is finally se-lected as the most adequate solution for establishing private cloud medical records.

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