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Research paper

Enterprise architecture framework selection for higher education using TOPSIS method

Siti KomariahHildayanti[1], Rian Rahmanda Putra[2], NazoriSuhandi[2], Ahmad Sanmorino[2], Fery Antony[2], Agustina Heryati[2], HartatiDeviana[3], RendraGustriansyah[2]*

[1]Faculty of Economic, Universitas Indo Global Mandiri, Indonesia
[2]Faculty of Computer Science, Universitas Indo Global Mandiri, Indonesia
[3]Department of Computer Engineering, Sriwijaya State Polytechnic, Indonesia
**Corresponding author E-mail:rendra@uigm.ac.id*

Abstract

In developing enterprise architecture (EA), it is necessary to adopt or select EA framework for enterprise architecture especially in the higher education. There are various frameworks that can be used for the development of enterprise architecture. There are several established EA frameworks in use today. Some of these frameworks were developed for very specific areas, while others have a wider function. This study aims to select the appropriate EA framework using TOPSIS method, applied to Higher Education. Seven eligible EA criteria are: grounded, cohesive, easy to customize, vendor free, technology independent, neutral-domain, and scalable will be processed by TOPSIS method. The calculation result with TOPSIS method shows that TOGAF is EA framework recommended to be implemented in higher education because it meets the criteria needed by EA framework.

Keywords:*Enterprise Architecture Framework; Higher Education; TOGAF; TOPSIS.*

1. Introduction

Enterprise Architecture (EA) is a holistic approach to managing the complexity of Information Technology (IT) from a business perspective. EA documents the structural and behavioural building blocks that make up the overall information system of the enterprises together with their relationships. EA provides a blueprint for an effective IT strategy and guides the controlled evolution of IT in a way that delivers business benefit in a cost effective way. An enterprise architecture framework can describe the underlying infrastructure, thus providing the groundwork for the hardware, software, and networks to work together. A good architecture and its corresponding documentation allow for ease of maintenance in order that the system does not become obsolete before it is even built. However, the increasing turbulence in the business environment and the larger number of alternatives with conflicting criteria has made the selection of EA frameworks a difficult and complex task [1].

There are several studies that have been performed to select and compare the appropriate EA framework to be implemented in the organization [1]–[4] but this does not provide a standard assessment for organization since has different requirements [5]. The EA framework selection problems are multi-criteria problems that embrace both qualitative and quantitative criteria. Nevertheless, the traditional selection methods over emphasize quantitative and economic analysis and often neglect to consider qualitative and non-economic data in the formal selection process. In this study, TOPSIS method [6] is applied to evaluate and select the appropriate EA framework for higher education based on seven criteria obtained from some literature and expert opinion. The TOPSIS approach is used because the selection of these criteria is subjective (having different requirements) for each higher education. The three EA frameworks considered in this study are Federal Enterprise Architecture Framework (FEAF), Zachman Framework for Enterprise Architecture (ZACHMAN), and The Open Group Architecture Framework (TOGAF). In order to establish a common ground for the framework comparison, the first stage is to study some of the existing EA frameworks. The second stage, create a method for comparing frameworks based on the expert's perspective. The third stage is comparing the frameworks to obtain and evaluate the appropriate EA for implementation in higher education using the TOPSIS method.

2. Related work

There are several studies related to the selection of the best EA framework in terms of various aspects/criteria that fit the research objectives, such as: [1], [3]–[5], [7]–[9].

Rouhani et al. provides a framework for comparing EA Implementation Methodology in three aspects: concepts, modelling, and process [7].

Kelemenis and Askounis have the idea of using TOPSIS approach for the personnel selection, but the criteria used are very different from this research because the implementation is different [9]. Likewise, Reddy et al. which integrates the AHP-GP approach to select software architecture [8].

Meanwhile, R. Yunis et al. have similar idea base, but they developed an EA model for higher education that refers the TOGAF [10] (not selecting a proven EA framework), so no research has the same idea/contribution as this study (selecting the best EA framework for applied to higher education).

As for Rui Rijo et al. developed EA framework for a hospital in Portugal by adopting relevant elements from four different EA frameworks (Zachman's, TOGAF, FEA and Gartner) with the aim

of improving the performance of medical appointment and patients' customer service [11], while David Goerzig adopted the EA Framework Zachman and TOGAF to build a digital transformation plan for small and medium-sized enterprises in mechanical engineering [12].
From several studies above can be seen that there is no research that tried to use EA framework that has been standard in determining EA framework for higher education.

3. EA overview

3.1. Zachman framework for enterprise architecture

John Zachman published the Zachman Framework for Enterprise Architecture in 1987 (as first EA framework). According to Zachman, the increased scope of design and levels of complexity of information systems implementations are forcing the use of some logical construct (or architecture) [13]. The Zachman Framework is based around the principles of classical architecture that establish a common vocabulary and set of perspectives for describing complex enterprise systems [14]. The Zachman Framework has six perspectives or views: Planner, Owner, Designer, Builder, Subcontractor, and User. The second dimension of Zachman's Framework deals with the six basic questions: what, how, where, who, when and why. The framework does not provide guidance on sequence, process, or implementation, but rather focuses on ensuring that all views are well established, ensuring a complete system regardless of the order in which they were established. The Zachman Framework has no explicit compliance rules since it is not a standard written by or for a professional organization. However, compliance can be assumed if it is used in its entirety and all the relationship rules are followed.

3.2. Federal enterprise architecture framework (FEAF)

The Federal Enterprise Architecture Framework was developed and published by the US Federal Chief Information Officers (CIO) Council. Government was following the industry trend of defining architectural frameworks to guide in the development of large, complex systems development. FEAF was in response to the Clinger-Cohen Act, 1996, which required Federal Agency CIOs to develop, maintain, and facilitate integrated systems architectures [15].The overriding goal of FEAF is to organize and promote sharing of Federal information for the entire Federal Government [16]. The architectural segments are developed individually, within structured guidelines, with each segment considered to be its own enterprise within the Federal Enterprise. The study includes the Federal Enterprise Architecture (FEA) - Practical Guide in discussions on FEAF because it provides the guidance to U.S. federal agencies for frameworks. FEA method is mainly concentrated on creating architectural method for governmental agency and allows for flexibility in the use of methods, work products, and tools to be used by the individual federal agencies [8].

3.3. The Open Group Architectural Framework (TOGAF)

The Open Group Architectural Framework (TOGAF) was first developed in 1995 and was based on the Department of Defence's Technical Architecture Framework for Information Management. TOGAF focuses on mission critical business applications that use open systems building blocks. A key element of TOGAF is Architecture Development Method (ADM) that specifies a process for developing enterprise architecture [17]. TOGAF explains rules for developing good principles, rather than providing a set of architecture principles. The three levels of principles support decision making across the entire enterprise; provide guidance of IT resources; and support architecture principles for development and implementation.

Table 1: Comparison of the Characteristics Enterprise Architecture Framework

Enterprise Architecture Framework	Characteristics
TOGAF	Enterprise architecture development methodology, History in defence, Open standard, Neutral, Broad acceptance, Holistic perspective, Process/planning tool.
Zachman	Positioning framework, Categorizing deliverables, Limited usefulness EA, History in manufacturing, Broad acceptance, Limited holistic Perspective, Planning tool
FEAF	Enterprise architecture reference framework, History in enterprise architecture planning, US Gov standard, Broad US Gov acceptance, Holistic Perspective, Planning and communication tool

3.4. TOPSIS method

TOPSIS (Technique for Order Preference by Similarity to an Ideal Solution) method is presented in Chen and Hwang (1992), with reference to Hwang and Yoon (1981). The basic principle is that the chosen alternative should have the shortest distance from the ideal solution and the farthest distance from the negative-ideal solution. The TOPSIS procedure consists of the following steps [6], [9].

a) Calculate the normalized decision matrix. The normalized r_{ij} value are calculated using the following equation (1):

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}}, \text{ i=1,2...m and j=1,2,...,n} \quad (1)$$

where r_{ij} is normalized matrix and x_{ij} is decision matrix.

b) Calculate the weighted normalized decision matrix. The weighted normalized value v_{ij} is calculated using the following equation (2):

$$v_{ij} = w_j.r_{ij}, \text{j=1..., m; and i=1,...,n} \quad (2)$$

where w_j is the weight of the j^{th} attribute or criterion.

c) Identify the positive-ideal solution (benefits) and negative-ideal solution (costs) with equations (3) and (4) as follow:

$$S_j^+ = \{(\text{maks}V_{ij} \mid j \in J), (\min V_{ij} \mid j \in J'), i=1, 2, 3...m\} = \{V_1^+, V_2^+ ... V_n^+\} \quad (3)$$

$$S_j^- = \{(\min V_{ij} \mid j \in J), (\text{maks}V_{ij} \mid j \in J'), i=1, 2, 3...m\} = \{V_1^-, V_2^- ... V_n^-\} \quad (4)$$

Where, J = {j=1, 2, 3... n and j are benefit criteria}, and J' = {j=1, 2, 3... n and j are cost criteria}.

d) Calculate the Euclidean distances from the positive ideal solutions (Sj+) of each alternative given by equation (5).

$$D_i^+ = \sqrt{\sum_{j=1}^{n} (V_{ij} - S_j^+)^2}, \text{ where i = 1, 2, 3... m} \quad (5)$$

Similarly, the Euclidean distances from the negative ideal solution (S_j^-) of each alternative is given by equation (6).

$$D_i^- = \sqrt{\sum_{j=1}^{n} (V_{ij} - S_j^-)^2}, \text{ where i = 1, 2, 3... m} \quad (6)$$

e) Calculate the closeness coefficient (C_i) for each alternative with respect to the positive ideal solution as given by equation (7).

$$C_i^+ = \frac{D_i^-}{D_i^+ + D_i^-}, \text{ where } 0 \le C_i^+ \le 1 \text{ dan } i = 1,2,..., m \quad (7)$$

f) Rank the alternative according to the closeness coefficient (C_i). The best alternative is one that has a higher value, because it is closer to a positive ideal solution.

4. Research methodology

In order to establish a common ground for the framework comparison, the first step is to study some of the existing EA frameworks. The second step, to create a method for comparing frameworks based on the expert's perspective. The third step is comparing the EA frameworks to obtain and evaluate the appropriate EA frameworks to be implementation in higher education using the TOPSIS method.

4.1. Studying some of the existing EA frameworks

In this study, the three EA frameworks are Federal Enterprise Architecture Framework (FEAF), Zachman Framework for Enterprise Architecture (ZACHMAN), and The Open Group Architecture Framework (TOGAF) which will be considered as an alternative, so that an appropriate EA framework can be obtained to be implemented in higher education.

4.2. Comparing frameworks based on the experts perspective

The leading enterprise-architecture methodologies are very different in their approaches. A total of more than 20 criteria related to the selection of EA framework in this study have beencollected from studies [1], [3], [4]. The relevance of these criteria to some higher education requirements is evaluated by two academic experts, so it can be concluded that there are seven relevant criteria as follows:

a) Reasoned (C_1)

Refers to a reasonable framework that can architecture that enables the creation of deterministic when there is a change and still maintain its integrity although deal with the changing of business and technology as well as unexpected demand.

b) Cohesive (C_2)

Refers to the cohesion of framework has a set of behaviors that will be balanced in its outlook and scope.

c) Adaptable (C_3)

Refers to framework can be adapted to changes that may occur so frequently within the organization.

d) Vendor-independent (C_4)

Refers to framework should not depend on certain vendors to actually maximize the benefits for the organization.

e) Technology-independent (C_5)

Refers to framework should not depend on certain technology to actually maximize the benefits for the organization.

f) Domain neutral (C_6)

Refers to framework should not only focus on a particular business domain.

g) Scalable (C_7)

Framework should operate effectively at the level of departments, business units, government and corporate level without loses focus and the ability to be able to apply.

These criteria are subjective, not all of these criteria might be relevant to others, and some might be more important than others. But, at least, this section could be the starting point for the evaluation. This study begins with interviews with experts from academia to provide an assessment for each criterion, and determine the criteria weights. The ratings will be set as follows:

1: Does a very poor job in this area
2: Does an inadequate job in this area
3: Does an acceptable job in this area
4: Does a good job in this area
5: Does a very good job in this area

4.3. Comparing the EA Frameworks Using the TOPSIS Method

The selected EA framework and these criteria will be made in the decision table, and then expert adjustments will be made. The value obtained from the adjustment of experts will be processed by TOPSIS method to obtain the EA framework ranking.

5. Result and discussion

This study was performed out step by step. After obtaining seven relevant criteria, experts (academics) were asked to determine the weight of each criterion through Focus Group Discussions as shown in Table 2.

Table 2: The Weight of Each Criterion

No	Criterion	Weight
1.	Reasoned (C_1)	3
2.	Cohesive (C_2)	4
3.	Adaptable (C_3)	5
4.	Vendor-independent (C_4)	4
5.	Technology-independent (C_5)	4
6.	Domain-neutral (C_6)	4
7.	Scalable (C_7)	4

It can be seen in Table 2 that the most important criterion in determining the EA framework in the high education is adaptable (C_3); That is because the high education is an organization that is always evolving. Similarly, the EA framework must be adapted to changes that may occur so frequently within the organization.

The next step was to determine the value of each criterion for each alternative (EA framework) as seen in the decision matrix in Table 3.The value of this table is obtained from interviews with experts.

Table 3: The Decision Matrix

Framework	C_1	C_2	C_3	C_4	C_5	C_6	C_7
Zachman	4	3	5	5	5	5	3
FEAF	3	5	3	5	5	3	4
TOGAF	5	5	5	5	5	5	5

The value of each criterion in Table 3 will be calculated by Equation (1) to obtain a normalized decision matrix (Table 4), then multiplied by the weight of each criterion of Table 2, so as to obtain a weighted normalized decision matrix (Table 5) for EA framework selection using Equation (2) .

Table 4: The Normalized Decision Matrix

Framework	C_1	C_2	C_3	C_4	C_5	C_6	C_7
Zachman	0,5657	0,3906	0,6509	0,5774	0,5774	0,6509	0,4243
FEAF	0,4243	0,6509	0,3906	0,5774	0,5774	0,3906	0,5657
TOGAF	0,7071	0,6509	0,6509	0,5774	0,5774	0,6509	0,7071

Table 5: The Weighted Normalized Decision Matrix

Framework	C_1	C_2	C_3	C_4	C_5	C_6	C_7
Zachman	1,6971	1,5623	3,2547	2,3094	2,3094	2,6038	1,6971
FEAF	1,2728	2,6038	1,9528	2,3094	2,3094	1,5623	2,2627
TOGAF	2,1213	2,6038	3,2547	2,3094	2,3094	2,6038	2,8284

Then the positive-ideal solution (S_i^+) and negative-ideal solution (S_i^-) for each criterion will be identified using equations (3) and (4). Table 6 shows the value of S_i^+ and S_i^-.

Table 6: The Positive and Negative Ideal Solutions

	C_1	C_2	C_3	C_4	C_5	C_6	C_7
S_i^+	2,1213	2,6038	3,2547	2,3094	2,3094	2,6038	2,8284
S_i^-	1,2728	1,5623	1,9528	2,3094	2,3094	1,5623	1,6971

For benefit criteria such as C_2, C_3, C_6 and C_7, the S_i^+ is the maximum value of all EA frameworks in the corresponding criteria; while for C_1, C_4, and C_5, the S_i^+ is the minimum value.

For cost criteria such as C_1, C_2, C_6, and C_7, the S_i^- is the minimum value of all EA frameworks in the corresponding criteria, otherwise it is the opposite.

The next step is to calculate the Euclidean distance for positive ideal solution and negative ideal solution of each alternative (EA Framework) using equations (5) and (6). The calculation results are as shown in Table 7.

Table 7: The Euclidean Distance for the Positive and Negative Ideal Solutions (D_i)

EA Framework	D_i^*	D_i^-
Zachman	1,5952	1,7204
FEAF	1,9544	1,1852
TOGAF	0,0000	2,4217

The last step of TOPSIS method will be calculated the closeness coefficient of the EA framework based on Equation (7). The closeness coefficient and rank of the EA framework was shown in Table 8.

Table 8: The Closeness Coefficient and Rank

EA framework	$\overline{C}_i$	Rank
Zachman	0,5189	2
FEAF	0,3775	3
TOGAF	1,0000	1

The results showed that TOGAF framework is the most appropriate EA framework used to develop EA in high education. This is because TOGAF characteristics that are 'reasoned', neutral, have a scalable approach and can integrate with different systems (adaptable). Meanwhile, the Zachman's Framework only provides sufficient value on 'reasoned', 'cohesive' and 'scalable' criteria, due to the characteristics of the Zachman's limited holistic perspective. Meanwhile, the FEAF framework in this study has the lowest score to be implemented as a college EA due to the characteristics of US Gov Standard, so it only provides sufficient appraisal on 'reasoned', 'adaptable' and 'neutral domains'.
Although the criteria used in this study tend to be subjective (the expert's perspective), but the result of this study can be used as a reference for preparing EA framework for higher education.

6. Conclusion

The results show that TOGAF is an appropriate EA framework for implementation in higher education, and TOPSIS method can be used to evaluate the EA framework in higher education. This research is still subjective, so it may be relevant to others, and perhaps some criteria are more important than others. However, at least, this study could be a starting point for other evaluation methods, such as the incorporation of methods in [6]. Further studies are also needed to find other criteria that may be important in the EA framework for higher education. We hope this research will stimulate new research in the field of EA framework and multi-criteria decision-making [18], [19] or toolkit development for ease of use of the EA framework [20], [21].

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