A Comparative Analysis of Emerging Enterprise Architecture Frameworks

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***Abstract*— With the evolution of the information technologies, numerous enterprise architecture frameworks have appeared trying to respond to the needs and requirements of business. For the reasons above, the main aim of this paper is to compare four emerging enterprise architecture frameworks according to the comparison parameters: Concepts, Modeling, and Process. The research method used to develop this work was a systematic literature review. For the statistical analysis was used the software package ATLAS.ti® version 7.5.4. Summarizing the results, showed that none of these emerging frameworks complies a 100% with all aspects previously mentioned.**

***Index Terms*— enterprise architecture – EA, emerging frameworks, systematic literature review, concepts, modeling, process**

I. Introduction

Information technology - IT evolves on a daily basis. The business sector does not remain oblivious to this reality. New organizational forms emerge, like virtual enterprises. These are defined as a temporary collaborative network of independent companies, formed to exploit a particular business opportunity [1, 2]. The core challenges on the Information age are: integration, agility and changes [3]. Enterprise Architecture aims to establish a proper alignment between business models and these information technologies. Therefore, the enterprise architecture frameworks are also evolving. In the contemporary literature, an increasing number of Enterprise Architecture (EA) frameworks can be found.

Mature concepts have been studied and compared in detail [4-7]. The literature shows that the academic and/or scientific community is trying to update the existing frameworks with the emerging technologies [8-12]. It also shows that some enterprise architecture frameworks emerge during this process in order to try to respond to the needs and requirements of these businesses, whether virtual or not [13-18]. However, some emerging ideas were not yet rated in their core properties. For the reason above, the main objective of this paper was made a functional, structural and systematic comparison between the emerging enterprise architecture frameworks. The objective was to obtain information on the main criteria for the design and implementation of an emerging business architecture framework, to discover the strengths and weaknesses presented in the proposed frameworks of this type. With this information, the first two authors will try, as future work, to design and implement a business architecture framework with business intelligence capabilities using computational intelligence and service-oriented architecture as the core.

The remainder of this paper is organized as follows. Section 2 discusses experimental method. Section 3 shows results and discussion. Section 4 provides final conclusions of this paper. Section 5 offers the acknowledgements, and finally, the references used in the paper.

II. Experimental

The research method used to develop this work was the systematic literature review. The objective of this research is to identify, evaluate and analyze the primary source of information, in order to respond a specific research question. This method provides information on existing lines of research and identifies potential research gaps for future works [19]. The method consists of the following phases: 1. the research question about this topic was: The emerging enterprise architecture frameworks were developed according to the key criteria for Enterprise Architecture Implementation Methodologies? 2. The criteria for inclusion or exclusion: papers where full text was available to the research team were included. 3. Data collection and analysis: the authors extracted the information below from the papers: Authors and years; Title; Publication type (conference or proceeding papers); Purpose or main goal; Material and Methods; Results; Conclusions; Recommendations; Quotations; Country of the first author. 4. The statistical analysis was performed using the qualitative data analysis software package ATLAS.ti® version 7.5.4.

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III. Results and Discussion

The main aim of this article was to make a comparison between these emerging frameworks according to the criteria set by previous comparative studies (Table I).

TABLE I. Compared Frameworks by the Respective Authors.

Framework	Lim, et al. [5]	Rouhani, et al. [4]	Sessions [6]	Magoulas, et al. [7]
Zachmann	✓		✓	✓
TOGAF		✓	✓	✓
DODAF	✓	✓		
Gartner		✓	✓	
EAP		✓	✓	
FEAF	✓	✓		
TEAF	✓			
LTGAF	✓			
GERAM				✓
E2AF				✓

The research unit decided to choose the more recent works (2013, 2014) due to the quick advance of technologies and platforms and used the comparison criteria proposed by Rouhani, et al. [4]. These comparison criteria are complemented with other concepts made by Zachman [20], who stated that a framework must be: Simple, Comprehensive, a language, a planning, a tool, a problem solving tools, Neutral. Winter and Fischer [21], whom argue that an EA framework provides: one or more meta-model(s) for EA description, one or more method(s) for EA design and evolution, a common vocabulary for EA, and maybe even, Reference models that can be used as templates or blueprints for EA design and evolution.

The same authors state that the components of an EA framework should be applicable for a broad range of corporations and government agencies [21]. Thus, the first comparison criterion is Concepts: according to Rouhani, et al. [4] EA concepts are generally addressed, including: definition of EA, alignment between business and IT, importance of repository, the association and communication among artifacts and EAIM strategy, governance among others.

The second parameter of the comparison is Modeling: a typical modeling comprises of the following major components: notation, syntax and semantics. Modeling different perspectives of enterprise are significant part of modeling that need to utilize in EAIM. Consequently, by using an appropriate modeling the EAIM could reduce the complexities of current and desired architecture, and transition plan effectively [4].

And the last one, is Process: For Rouhani, et al. [4], Enterprise Architecture Implementation Methodology – EAIM, emphasizes the set of process and parts performed as part of the EA life cycle. A useful EAIM should cover the following stages, enterprise modeling, current architecture analysis, desired architecture analysis, managing and providing detailed design of projects, describing controlled transition plan, and implementation. EAIM that covers all parts of the EA development by considering EA concepts is a consistent and complete methodology. The results of the comparison are summarized in table II and discussed below:

TABLE II. Emerging Frameworks Comparison.

	EA SCENARIO ANALYSIS - Leyva-Vázquez, et al. [14]	EA ANALYTICS - Schmidt, et al. [22]	SOA, BIG DATA AND CLOUD - Zimmermann, et al. [18]	EA INTELLIGENCE - Veneberg, et al. [23]
CONCEPTS				
Alignment	L	M	H	M
Artifacts	L	M	M	H
Governance	L	H	M	L
Repository	L	M	L	L
Strategy	L	M	L	L
MODELING				
Easy to use	M	M	L	M
Easy to learn	M	M	L	M
Traceability	L	M	L	M
Consistency	M	H	L	L
Different views	M	H	M	L
Complexity	M	H	M	H
Dynamic	L	H	L	L
PROCESS				
Requirement	L	M	M	L
Step by step	L	L	L	H
Detailed design*	L	L	H	L
Implementation*	L	L	L	L
Guidelines	L	L	L	L
Maintenance	L	L	M	L
Continual	L	M	M	M

According to Rouhani, et al. [4] the parameters are considered as below: **H**: high consideration or detailed and clear description. **M**: medium consideration or little description. **L**: low consideration or high level description. * This part is included here because the author compared EA implementation methodologies.
Source: The evaluation was made by research unit.

The work of Leyva-Vázquez, et al. [14] propose a framework for identification, analysis and ranking of EA future scenarios using fuzzy cognitive maps – FCM and Ordered weighted averaging - OWA. According to the authors, scenario analysis helps to identify different alternatives to attain a future state (useful for future decision support systems and knowledge management system development). It is a strategic planning method to make flexible planning, often used in enterprise-wide technology management. By using the first technique, complex systems can be modeled and simulated. FCM incorporates ideas from artificial neural networks and fuzzy logic [24]. Provides a more flexible and more realistic representation scheme for dealing with knowledge [25]. FCM also offers the modeling mechanism for linking the strategic goals with the Object Oriented models [26] and the second one technique, can be interpreted as a degree of risk acceptance [27]. Decision maker risk attitudes can be then encoded in the form of OWA operators [14]. This framework was developed integrating knowledge from experts (this means that is necessary to have specialist or experts acting in the modeling process). The disadvantage from modeling with FCM is the lack of quantitative analysis of

results for ranking of alternatives [28]. The authors mentioned those properties from the techniques, however, in the framework is not visible this alignment between the strategic goals and the business model. For these reasons, the rating for the EAIM indicators are generally in low. Majority of the implementation process are low because they didn't propose an implementation methodology.

The work of Schmidt, et al. [22] introduce a framework for enterprise architecture analytics, which we are integrating from an extended service-oriented enterprise architecture reference model in the context of Big Data analytics for architecture, new decision supports methods for architecture alignment, and an original architecture maturity approach. This framework was made using fundamental concepts and definitions from Software Architecture, Architecture Reference Model, Reference Architecture, Service-oriented Enterprise Architectures, architectures for Services Computing and Cloud Computing, Cloud Reference Architectures from different authors. The Enterprise Services Architecture Reference Cube – ESARC was their growing original Service oriented Enterprise Architecture Reference Model, which provides an integral EAM model for main interweaved architectural viewpoints. According to the authors, this framework leverages the huge amounts of data available in today's virtualized infrastructures and exploits those using technologies from the context of Big Data. By this means, it is possible to use both semi- and un-structured data for infrastructure systems. Unfortunately, the authors did not apply the proposed framework in a real industry sector. As a future work, they want to evaluate their framework in different contexts, and investigate how to establish a suitable information and decision support basis for Industry or other context specific criteria implementing an empirical study observing and evaluating risks of a data driven analysis (e.g. forecast error, metric problems).

The Zimmermann, et al. [18] work provides a set of reference architectures and architecture reference models geared towards a cloud-based SOA for Big Data applications. The so-called Business and Information Reference Architecture (BIRA) support alignment of business and IT. The reference models presented include different viewpoints and can be used for the detailed design of enterprise-specific architectures. To a certain degree, quality assurance and continual improvement are discussed. However, the authors do not provide a method to derive a company-specific architecture, nor do they show how to implement one. Hence, the ratings for the EAIM indicators are generally on the lower end of the scale.

Veneberg, et al. [23] propose a method for solving business concerns using combined information from operational and EA data. A step by step explanation is given and each activity has a defined set of input and output documents. As the method is applied to support decision making, reduction of complexity is supported in several steps. For example, the number of examined data sources and EA elements is reduced as much as possible and the importance of adequate data visualization for decision makers is stressed. However, the method is currently restricted to decision support and target achievement control. It does not consider the overall strategy of the enterprise, nor does it provide guidance on how to actually make changes in the EA. Thus, only a few indicators get a high rating as the majority of EAIM attributes is not very well supported.

As summary of the results, we can state that the frameworks with higher score in all aspects from the comparison criteria is the work of Schmidt, et al. [22], followed by Veneberg, et al. [23] and the last two, are Zimmermann, et al. [18] and Leyva-Vázquez, et al. [14], respectively. The framework with the worst evaluation (lower score) is the work of Leyva-Vázquez, et al. [14].

According to the main criteria, **in concepts**: almost most of mentioned frameworks cover all concepts. Alignment and Artifacts are supported by most selected frameworks; in contrast Repository and Strategy were not utilized in most of frameworks. (These results differ with those obtained by Rouhani, et al. [4]). **In modeling**: the works of Schmidt, et al. [22] and Veneberg, et al. [23] are in same situation (high and medium grade). The work of Leyva-Vázquez, et al. [14] has fluctuates situation (in some attributes has medium grade and in the others has low grade) and the work of Zimmermann, et al. [18] has the lower grade in this category. Selected frameworks do not have specific plan for depiction complexity and dynamic aspects of EA (These results are similar to obtained by Rouhani, et al. [4]. **In process**: in this category, the results are very different to obtained by [4] because the authors evaluated Enterprise Architecture Implementation Methodologies – EAIMs and the selected emerging enterprise architecture frameworks are not implementation methodologies. However, the parameters also are usable for the comparison. Step by step structure, detailed design, implementation, guidelines and maintenance are the lower attributes in the selected frameworks. They need to consider more due to lack of consideration in most of the evaluated frameworks. Requirement and Continual are most usable attribute in the selected frameworks.

IV. Conclusions

This paper presented a comparative analysis of emerging Enterprise Architecture Frameworks based on the Rouhani, et al. [4] comparison parameters. As conclusion of the paper we can state that none of the emerging frameworks are fully completed, all of them have strengths and weaknesses. According to results, none of the compared works complies a 100% with all aspects mentioned by Zachman [20], Winter and Fischer [21] and Rouhani, et al. [4]. Our recommendation for future work is to try to get the strengths of the better framework (higher score items) and trying to obliterate their weaknesses (step by step, detailed design, implementation and guidelines). It would be great if the enterprise architects began using hybrid frameworks and documenting their experiences. This information is very relevant for the first two authors, because they want to purpose an emerging enterprise architecture framework

using computational intelligence and service-oriented architecture as core for the development of business intelligence.

APPENDIX A TAXONOMY OF THE FOUND WORKS

According to the main objectives (or goals) and titles of the found works (papers), they were classified as follow:

a. **Emerging Frameworks**: This category represents all jobs that design, redesign or improve any previously established framework (i.e. TOGAF, EAP, Zachman, etc.) using new techniques or procedures with the primary goal of improving the integration of all layers an enterprise architecture (infrastructure, data, applications, business, strategies). This category includes the work of [13], [14], [29], [22], [23], [3], [30], [15], [16], [17] and [18].

b. **Methods for improvement or redesign Enterprises Architectures Frameworks**: It is important to mention that this category could include some emerging frameworks because they may propose any kind of improvement or redesign of any component of the EAF. This category includes the works of [31], [23], [32], [33], [34], [35], [36] and [37].

c. **Frameworks Using Service Oriented Architecture – SOA**: This category includes works of [38], [3], [39], [13], [18], [16] and [30].

d. **Frameworks for Decision Making support**: For this category, the authors found the works of [14], [36], [23] and [40].

e. **Frameworks using Cloud Computing**: This includes the works of [22], [13], [3] and [18].

f. **Frameworks using or designing software for reference model**: Include the works of [41], [42] and [43].

g. **Frameworks using Ontologies**: For this category were found the works of [36] and [44].

h. **Frameworks to evaluate maturity models of Enterprise Architecture**: In this category we can find the works of [33] and [22].

i. **Works evaluating quality attributes**: Within this category, the authors found works of [5] and [40].

j. **Works Modeling Contextual concerns**: We can find the works of [45] and [42].

k. **Works making comparison between EAs**: In this category we found the works of [5] and [4].

l. **Frameworks using Resilience**: This category was included because [30] presented this work at the 2009 IEEE International Systems Conference Proceedings in Vancouver - Canada.

m. **Works with EA complements**: This category is represented by [46].

n. **Institutionalization of EA**: This is represented by [47].

o. **Emphasize on Architects skills**: In this category, we count with the work of [48]

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