Comparative analysis of enterprise architecture frameworks

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***Abstract*— Complex, critical systems require to apply model-based system engineering (MBSE) practices and use standardized methodologies and frameworks that help define the system in a commonly recognized way. The enterprise architecture framework helps determine how information, business, and technology work together. It brings more discipline to the organization by standardizing and consolidating processes to ensure better consistency. This has become a necessity for companies seeking to organize various architectural perspectives into a holistic and unified view. There are several frameworks that help companies implement architecture efficiently. This opens up the question of what set of criteria based on a system of systems principles can be used for comparative analysis of enterprise architecture framework in order to select the best one. This paper proposes five criteria that include weights and presents the results of a comparison of six enterprise architecture frameworks.**

Keywords*— *Comparative analysis, Enterprise architecture framework, Unified Architecture Framework

I. Introduction

In the age of innovation, people are surrounded by many systems designed to facilitate everyday life, accelerate processes, or even save human life. The growing complexity of the problems requires the problem-solving to be transferred to the systemic level. Nowadays, there are problems that need to be taken into account through a system thinking in order to address new challenges such as the internet of things, autonomous traffic management and so on.

Model-Based Systems Engineering (MBSE) is systems engineering methodology which emphasizes the application of rigorous visual modeling principles. Models are created to deal with complexity, they allow to understand an area of interest, encourage reuse and improve quality [1]. Complex real-life problems require to apply MBSE practices in the level where independently from one another evolving in time systems communicate to achieve a common goal. This is the level of system of systems (SoS). The Department of Defense (DoD) Defense Acquisition Guidebook defines the SoS as a "set or arrangement of systems that results when independent and useful systems are integrated into a larger system that delivers unique capabilities" [2]. SoS is a large complex system that needs to be defined accurately and consistently.

Any complex system can be viewed from several different angles, each of which can be depicted in various architectural perspectives. In order to organize these diverse architectural perspectives into a holistic and unified view, it is necessary to use an enterprise architecture framework that was originally designed by John Zachman. Fig. 1 provides the Zachman framework.

According to the [3] "the framework successfully combines people, data and technology to show a comprehensive view of the inter-relationships within an information technology organization". Framework helps to develop a complex, integrated, cohesive and comprehensive solution and can speed up the architecture development process.

The framework structure the architecture description into domains, layers or images, and suggests using views - diagrams and matrices - to document each concept. The structured description of architecture allows to make systemic decisions on all system components and make long-term decisions about new design requirements, sustainability and support. Organization architecture framework (EAF) defines principles and practices how to design an enterprise or system of systems architecture.

	Why	How	What	Who	Where	When
Contextual	Goal List	Process List	Material List	Organizational Unit & Role List	Geographical Locations List	Event List
Conceptual	Goal Relationship	Process Model	Entity Relationship Model	Organizational Unit & Role Rel. Model	Locations Model	Event Model
Logical	Rules Diagram	Process Diagram	Data Model Diagram	Role relationship Diagram	Locations Diagram	Event Diagram
Physical	Rules Specification	Process Function Specification	Data Entity Specification	Role Specification	Location Specification	Event Specification
Detailed	Rules Details	Process Details	Data Details	Role Details	Location details	Event Details

Fig. 1. The Zachman framework for Enterprise Architecture [4]

In this paper, we focus on the criteria for comparing enterprise architecture frameworks. The question is how to evaluate different enterprise architecture frameworks: what set of criteria based on a system of systems principles to use in order to select the best framework.

In this paper, we propose a new set of criteria including weights and criteria rating which can be used for comparative analysis of enterprise architecture frameworks.

The rest of this paper is structured as follows: in Section 2, the related works are analyzed; in Section 3, the overview of enterprise architecture is provided; in Section 4, the set of criteria with weight are provided to perform a comparison; in Section 5, the achieved results, conclusions, and future work directions are indicated.

II. Related Works

There is a large number of research papers on the comparison of enterprise architecture frameworks. Most of them are proposing are criteria how to compare EAF, other

ones propose criteria on how to compare EAF in the specific area like SOA, EAF implementation etc.

A number of authors compare organization architecture frameworks to offer a more comprehensive and accurate EAFs comparison approach, these studies has been defined in [5], [6], [7], [8]. Paper [5] investigates the concept of architecture by examining six AF: ZF, 4+1 Views, FEAF, RM-ODP, TOGAF, DoDAF. Authors of this paper proposed to compare EAF by fundamental elements such as their goals, inputs and outcomes. The proposed criteria were evaluated on the basis of three estimates: „Y" – explicitly supports an element, „N" – does not support an element, „P" – partially supports or eludes to support an element. In [6] article is compared and contrasted four distinct approaches to the representation and management of models relating to enterprise complexity, ZF, ISO 15704, ISO/CEN 19439 and ISO/IEC 15288. Approaches compare has been performed by archetype dimension, prototype models, purposive dimension, life history, populating with artifacts, profile of change and managing change. Paper [7] provides a guidance in the selection of an EAF that meets the needed criteria. In this paper is performed a comparison of five frameworks: ZF, DoDAF, FEAF, Treasury Enterprise Architecture Framework (TEAF) and TOGAF. The authors of this paper proposed to compare EAFs by tree criteria: (i) views/perspectives - planner, owner, designer, builder, subcontractor, user; (ii) abstractions - what, how, where, who, when, why; (iii) the systems development life cycle – planning, analysis, design, implementation, maintenance. In [8] article author compares following four leading EAF: ZF, TOGAF, FEAF and GEAF. A comparative analysis is performed by ten criteria: taxonomy completeness, process completeness, reference-model guidance, practice guidance, maturity model, business focus, governance guidance, partitioning guidance, prescriptive catalog, vendor neutrality, information availability, time to value. Each EAF is ranked in each of ten criteria and the rating from 1 (very poor) to 4 (very good) is assigned.

Comparative analysis of enterprise architecture frameworks has been performed in other studies to compare EAF in various areas than the framework definition, these study has been defined in [9], [10]. In paper [9], a comparison of EAF has been designed based on the identifies parameters. These parameters identify the gaps in the maturity model. In [10] publication is proposed three major aspects to compare enterprise architecture framework implementation methods: (i) concepts – definition of EA, alignment between IT and business, the association and communication among artifacts; (ii) modeling - notation, syntax and semantics; (iii) process - activities and steps for enterprise architect and business analyzer in EA implementation.

In conclusion, all the analyzed papers and articles to compare enterprise architecture frameworks encounter several common issues: (i) unified architecture framework (UAF) is not included in the comparison, (ii) unsupported weight of the comparison criteria, (iii) it is difficult to interpret the results of EAF comparison, there is not provided the formal result of a comparison.

Overall, researches carried out in this area mainly provide a set of criteria for a general EAF comparison, regardless of the area where that EAF will be applied. I am proposing a more specific, easy to apply set of EAF comparison criteria, applicable to the majority of EAF. The proposed approach in combination with SoS principles will provide a set of comparison criteria with weights to compare EAF. This will help to make a more accurate comparison that is specifically based on the SoS domain and will provide the appropriate EAF selection that will be applied to complex system modeling.

III. Overview of Enterprise Architecture Frameworks

Below is provided a brief description of six enterprise architecture frameworks that are used in this study.

Department of Defense Architecture Framework (DoDAF). This framework is developed for the United States Department of Defense (DoD) that provides visualization infrastructure for specific stakeholders concerns through viewpoints organized by different views. It helps to ensure that architectural artefacts are defined and characterized consistently according to the specific project or mission needs, in order to be "fit-to-purpose". DoDAF organization framework assists managers to make critical decisions more effectively by organizing information sharing across the Department, Joint Capability Areas (JCAs), Mission, Component, and Program boundaries [11]. DoDAF focuses on architectural data rather than architecture artifacts. The framework defines how to specify systems of system using the architectural terms within DoD [12]. The development and documentation of weapons and IT systems in USA must be conducted in accordance with the DoDAF guidelines.

NATO Architecture Framework (NAF). NAF is developed by the North Atlantic Threaty Organization (NATO) and derived from DoDAF Enterprise Architecture. The goal of NAF is to provide a standard for developing and describing architectures for both military and business use [13]. The NAF is designed to ensure that architectures developed adhering to it can be understood, compared, justified and related across many organizations, including NATO and other National Defense initiatives. NAF defines: methodology, viewpoints, stakeholder viewpoints and meta-model [13].

Ministry of Defense Architecture Framework (MODAF). This framework is developed for the British Ministry of Defense to support defense planning and change management activities. MODAF ensures accurate, comprehensive and consistent collection and presentation of information, helping to understand complex issues [14]. The main benefits of MODAF are the improvement of interoperability and implementation between Systems. The framework supports a variety of MOD processes, such as: capability management, acquisition and sustainment. MODAF architectures are designed as consistent, adjacent models that provide a comprehensive view of the enterprise. MODAF defines set of various relationships that can be used to integrate the architectural elements [14].

Unified Architecture Framework (UAF). UAF was initially created as UPDM 3.0, responding to the needs of UML / SysML and military communities to create a standardized and consistent enterprise architecture based on the U.S. Department of Defense Architecture Framework (DoDAF) and the UK Ministry of Defense Architecture Framework (MODAF) [15]. UAF consists of three main components: (i)

framework – a collection of domains, model kinds, and viewpoints, (ii) metamodel – a collection of types, tuples, and individuals used to construct views according to the specific viewpoints, (iii) profile – SysML based implementation of the metamodel to apply model-based systems engineering principles and best practices while building the views. UAF provides a set of rules to allow users to create a consistent enterprise architecture (as models) based on common enterprise and system concepts with rich semantics. These models then become the repositories from which various views can be extracted [16].

Federal Enterprise Architecture Framework (FEAF). This framework is developed for the U.S. federal government. It provides a common approach for the integration of strategic, business and technology management as part of organization design and performance improvement [17]. The government through organizations practice to define the enterprise architecture, used the EAF to assist the development of large, complex systems development processes. Architectural segments are created individually, according to the structural guidelines, each segment is considered to be its own enterprise within the Federal Enterprise.

The Open Group Architectural Framework (TOGAF). This framework is based on the Department of Defense's Technical Architecture Framework for Information Management [18]. TOGAF focuses on mission-critical business applications that use open systems building blocks. TOGAF provides and explains the rules, creating good principles for system architecture development. TOGAF includes three levels of principles: (i) support decision-making throughout the enterprise, (ii) provide guidance of IT resources; (iii) support architecture principles for development and implementation.

IV. Comparison of Enterprise Architecture Frameworks

Currently there is a wide selection of enterprise architecture frameworks. Comparison analysis is required to select the most appropriate framework. In order to more accurately compare the EAF, we suggest using the comparison criteria including ratings and weights. The criteria for the comparative analysis of the enterprise architecture frameworks are as follows:

- **Domain support (DS)** – level of domain support by EAF. The criterion identifies the universality of the framework.
- **Modeling languages openness (MLO)** – level of modeling languages openness. The criterion helps to evaluate whether the modeling language used by the EAF can be modified. Indicates whether the organization that manages the modeling language is open or private.
- **Information availability (IA)** – level of information availability of EAF. The criterion specifies how easily a user can find additional information, material, presentations that help to improve a user knowledge of certain EAF.
- **Tool support (TS)** - level of framework support by modeling tools. The criterion identifies the availability to use the framework in practice through a modeling tool.
- **Prevalence by researchers (PR)** - level of framework prevalence by the research's community. The criterion helps to evaluate whether the framework is being investigated or elaborated in scientific works.

In order to more accurately compare EAF, the set of criteria which are provided above should be ranked. TABLE I provides the rating definitions.

TABLE I. Criteria Ratings

Scale	Rating	Definitions
4	Very Good Full Support	Very good or fully criteria support.
3	Good Acceptable	More than weak criteria support.
2	Weak Less than Acceptable	Inadequate or very poor criteria support.
1	Very Poor Unacceptable	No criteria are met. Very poor criteria support.

To determine the importance of the criteria, it is proposed to assign a weight for each criterion. The total number of assigned weights should be 1. TABLE II provides the weighted rating of criteria.

TABLE II. Quantitively criteria and weights

Criteria	Weight	Justification
Tool support	0.3	The criterion refers to the practical application of the framework.
Domain support	0.3	The criterion refers to the application of the framework in different domains, which allows the company to define various areas using the same framework.
Modeling languages openness	0.2	The criterion refers to modifications to the modeling language.
Information availability	0.1	The criterion refers to the level of dissemination of the framework information.
Prevalence by researchers	0.1	The criterion refers to the level of framework popularity by researcher's community. It shows whether there are ongoing studies in this area.

When each criterion is ranked, it is necessary to calculate a weighted average that helps to show the best framework from the others. Below is provided the comparison formula (1).

$$\bar{X} = \frac{\sum_{i=1}^{n} \omega_i x_i}{\sum_{i=1}^{n} \omega_i} \quad (1)$$

$\bar{X}$- weighted average
ω_i– weighted criteria
x_i– rate criteria

TABLE III provides the results of compared six enterprise architecture frameworks which are briefly introduced in section III. The comparison has been performed using the proposed set of criteria.

TABLE III. Comparison of enterprise architecture frameworks

EAF/ Criteria	DoDAF	NAF	MoDAF	UAF	FEAF	TOGAF
Domain support	1	1	1	3	1	2
Modeling Language openness	1	1	1	4	1	1
Information availability	3	2	3	1	1	4
Tool support	3	3	3	2	2	3
Prevalence by researchers	4	2	3	1	1	4
TOTAL	1.9	1.6	1.8	2.8	1.2	2.3

According to the results of the comparison, the best frameworks according to the criteria are listed below.

- Domain support – UAF
- Modeling Language Openness – UAF
- Information Availability – TOGAF
- Tool Support – DoDAF, NAF, MoDAF, TOGAF
- Prevalence by researchers - DoDAF, TOGAF

However, the Unified Architecture Framework according to the comparison result has been identified as best framework from other.

CONCLUSIONS

In this paper, we have analyzed the set of criteria which are used to perform a comparative analysis of enterprise architecture framework. The analysis disclosed that a wide variety of different sets of criteria are used which help to select the best framework. However, most of the criteria do not include weights that help determine the priorities of the criteria. The lack of criteria weights and ratings make it difficult to interpret the results of the comparison. Also, none of the proposed set of criteria is used to compare the newest framework – unified architecture framework. We have determined the need for criteria with weights and ratings.

In this paper, we propose a new set of criteria including weights and criteria rating which can be used to carry out an accurate and detailed comparative analysis of enterprise architecture frameworks. The set of criteria includes five criteria: domain support, modeling language openness, information availability, tool support and prevalence by researchers. For each criterion is assigned a weight indicating the importance and priority. Also, the criteria have a rating that determines the framework support under certain criteria, a rating of 1 (very poor) to 4 (very good).

Currently, this paper is oriented to the set of criteria which helps to evaluate different enterprise architecture frameworks in order to select the best framework. In the near future, we are planning to expand our research on enterprise architecture frameworks, especially on Unified Architecture Framework, to explore the possibility of performing an engineering analysis and behavioral modeling using a standard-based method.

REFERENCES

[1] J. Bankauskaite, A. Morkevicius, "An Approach: SysML-based Automated Completeness Evaluation of the System Requirements Specification," in *International Conference on Information Technologies (IVUS)*, Kaunas, Lithuania, 2018.

[2] "Defense Acquisition Guidebook," 26 February 2017. [Online]. Available: https://contractingacademy.gatech.edu/wp-content/uploads/2014/06/Defense-Acquisition-Guidebook-%e2%80%93-Feb.-26-2017.pdf.

[3] T. E. Consortium, "Enterprise Architecture Body of Knowledge," [Online]. Available: http://eabok.org/about.html. [Accessed 10 02 2019].

[4] J. A. Zachman, "The Concise Definition of The Zachman Framework by: John A. Zachman," 2008. [Online]. Available: https://www.zachman.com/about-the-zachman-framework. [Accessed 5 January 2019].

[5] A. Tang, J. Han and P. Chen, "A comparative analysis of architecture frameworks," in *1th Asia-Pacific Software Engineering Conference*, Busan, South Korea, 2004.

[6] R. Martin, E. Robertson, "A Comparison of Frameworks for Enterprise Architecture Modeling," *Conceptual Modeling - ER 2003*, vol. 2813, pp. 562-564, 2003.

[7] L. Urbaczewski, S. Mrdalj, "A comparison of enterprise architecture frameworks," no. Inform Syst. 7, 2006.

[8] R. Sessions, "Comparison of the Top Four Enterprise Architecture Methodologies," 2007.

[9] S. Pulparambil and Y. Baghdadi, "A Comparison Framework for SOA Maturity Models," in *2015 IEEE International Conference on Smart City/SocialCom/SustainCom (SmartCity)*, Chengdu, 2015.

[10] B. D. Rouhani, M. N. Mahrin, F. Nikpay and P. Nikfard, "A Comparison Enterprise Architecture Implementation Methodologies," in *2013 International Conference on Informatics and Creative Multimedia*, Kuala Lumpur, 2013.

[11] Department of DefenseOffice of the Assistant Secretary of Defense (OASD) for Network Infrastructure and Integration, "The DoDAF Architecture Framework Version 2.02," 2010.

[12] Department of Defense, "DoD Architecture Framework Version 2.02, Manager's Guide," 2015.

[13] North Atlanic Treaty Organization, "NATO Architecture Framework, Version 4," 1 August 2018. [Online]. Available: https://www.nato.int/cps/en/natohq/topics_157575.htm. [Accessed 9 January 2019].

[14] Minestery of Defense, "Guidance MOD Architecture Framework," 12 December 2012. [Online]. Available: https://www.gov.uk/guidance/mod-architecture-framework. [Accessed 02 02 2019].

[15] OMG Group, "Unified Architecture Framework Profile (UAFP) version 1.0," 2017.

[16] OMG Group, "UAF specification at OMG," 2017.

[17] Executive office of the president of the united states, "FEA Consolidated Reference Model Document Version 2.3," October 2017. [Online]. Available: https://web.archive.org/web/20090202182509/http://www.whitehouse.gov/omb/assets/fea_docs/FEA_CRM_v23_Final_Oct_2007_Revised.pdf. [Accessed 14 January 2019].

[18] The Open Group, "The Open Group Architectural Framework," 2015. [Online]. Available: www.opengroup. org /architecture/togaf7-doc/arch/. [Accessed 02 02 2019].