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Enterprise architecture frameworks. An immersion in its complexity

Marcos de arquitectura empresarial. Una inmersión en su complejidad

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ABSTRACT

This paper addresses the subject of Enterprise Architecture from the role of its working groups in its development and evolution. These have been a fundamental part of most of the architecture projects carried out at an international level. The work starts with a conceptualization of the frameworks, grouping the theoretical findings in several conceptual aspects. Subsequently, a balance is made between the positive and negative elements of the frameworks, ending with an assessment of their impact on the evolution of enterprise architecture initiatives. Finally, a broad set of frameworks is surveyed, including information on their countries of origin, year of publication, author, etc. The resulting list reflects the complexity of the universe of frameworks and the wide variety of options for implementing enterprise architecture projects.

Descriptors: Enterprise Architecture; frameworks; organizational engineering. (UNESCO Thesaurus).

RESUMEN

En el presente trabajo se aborda la temática de la Arquitectura Empresarial desde el papel de sus marcos de trabajo en su desarrollo y evolución. Estos, han sido parte fundamental de la mayoría de los proyectos de arquitectura que se llevan a cabo a nivel internacional. El trabajo parte de una conceptualización de los marcos de trabajo, agrupando los hallazgos teóricos en varias vertientes conceptuales. Posteriormente, se realiza un balance entre los elementos positivos y negativos de los marcos de trabajo, finalizando con una valoración de su impacto para la evolución de las iniciativas de arquitectura empresarial. Finalmente, se estudia un amplio conjunto de marcos, con información sobre sus países de origen, año de publicación, autor, etc. El listado resultante, refleja la complejidad del universo de los marcos de trabajo y la amplia variedad de opciones para implementar proyectos de arquitectura empresarial.

Descriptores: Arquitectura empresarial; marcos de trabajo; ingeniería organizacional. (Tesauro UNESCO).

INTRODUCTION

In the context of the complexity of today's organizations and the relevance of factors such as agility, flexibility and process digitization, holistic and radical initiatives are necessary. One of these solutions has become highly accepted in both business and academic circles: enterprise architecture (Telnov et al., 2024). Although enterprise architecture as a discipline is relatively recent, its true origins go back well before the 1980s when processes and procedures were still structured manually. Its origins date back to 1987 when J. A. Zachman published his famous IBM magazine article on the topic of information systems architecture (Zachman, 1987).

The balance among the levels of strategy, business and information systems is shifting as organizations are affected by rapid changes in a competitive and dynamic environment (Hindarto & Putra, 2024b). In this context, enterprise architecture (EA) is seen as a promising approach to improve business alignment. Managing the complexity of today’s organizations remains a constant challenge, causing enterprise agility to become one of the most far-reaching concerns in the business world. Enterprise Architecture helps to address important challenges like achieving sustainability of the business in its market (Kawtar et al., 2022), ensuring process continuity, ensuring robust performance (Petrov et al., 2022) and coping with the digitization of business processes (Schubert et al., 2023).

Enterprise Architecture has revolutionized the organizational world as it integrates systems in an environment of operational efficiency and market responsiveness (Hindarto and Putra, 2024a). It provides a roadmap for the integration of different technological elements, databases and applications in the organization's ecosystem, always with a tendency to standardize processes and create a unified framework (Hindarto& Putra, 2024b). It is accepted among business initiatives for its ability to implement agile systems, which at the same time can deal with the complexity of

production processes (Bokolo & Sobah Abbas, 2022; Brée & Karger, 2022) and provide solutions to the integration of people, technologies and systems.

Enterprise architecture represents the symbiotic adoption of information technology as a transformative element of organizational culture (Petrov et al., 2022) and is capturing the attention of experts, academics and business practitioners. It is an innovative combination of architectural discipline and business management, which poses a technical development (Oberle et al., 2023) and includes the essential elements of an organization (Apriyandi, 2024). It is used as a systematic and tactical strategy that encompasses the design, integration and management of vital organizational elements.

Other elements that have contributed to the rise of enterprise architecture are its focused contributions to digital transformation, to managing organizational complexity (Bokolo & Sobah, 2022), ensuring consistency of organizational objects (Brée& Karger, 2022), harmonising technological needs and fostering agility (Ettahiri & Doumi, 2022). Enterprise architecture is the first discipline to bridge the communication gap between the business and its stakeholders by creating several complementary perspectives (Fernández et al., 2022).

Despite many theoretical studies, approaches to the topic and recent developments, a globally accepted definition of enterprise architecture has not been achieved (Schubert et al., 2023). The origin of the term "architecture" comes from an analogy with construction, which has been used before in the software industry. As there is no single definition of enterprise architecture, it can be considered an evolving concept, with various conceptual interpretations. (Ari & Utami, 2022)

One of the most universally accepted definitions is provided by the ISO/IEC/IEEE standard (Standard 42010:2011), cited by Schubert et al. (2023) and Apriyandi (2024), which states that "it is the fundamental organisation of a system, embodied in its components, their relationships with each other and with the environment, and the principles that govern its design and evolution".

Enterprise architecture constitutes a set of properties of a system for the integration of its elements, relationships and design principles, which captures the essence of an enterprise and its basic organization (Bokolo & Sobah, 2022). It also establishes the standardization requirements of the company's operating model, including the current state, future state and roadmap for transition to the future state (Hindarto & Indrajit, 2023). It is also considered a comprehensive discipline, providing processes, tools, principles and structures (Bokolo & Sobah Abbas, 2022) to achieve a set of high-level comprehensive descriptions (Ari & Utami, 2022) that are logically linked to each other. It is also defined as a comprehensive and holistic description of an organization, which cooperates in the deployment of all dimensions of a firm (Chávez, 2021).

Enterprise architecture is fundamental to help organize and strategically monitor changes in infrastructure and operational procedures (Hindarto & Indrajit, 2023). It is crucial for organizational design and the process of timely management of organizational resources (Schoonderbeek & Proper, 2024; Ningsih et al., 2024). Enterprise architecture has now become the basis for building corporate information systems (Judijanto et al., 2023), providing flexibility (Hindarto & Putra, 2024a), interoperability, efficiency, sustainability and complexity management (Apriyandi, 2024). Its contribution is fundamental to projects such as "*Society 5.0*" or the Internet of Things (Hindarto et al., 2024b), as it has the potential to merge cyberspace and physical space, creating a people-centric environment (Ko¸c et al., 2022; Bokolo & Sobah, 2022; Ettahiri & Doumi, 2022).

The actual work aims to address the issue of enterprise architecture frameworks through their conceptualization, the analysis of their positive impact on enterprise architecture, the analysis of their weaknesses and the update of the current universe of models. The research vindicates the importance of frameworks in the development of enterprise architecture as a discipline. These have been instrumental in delivering value through

enterprise architecture, facilitating the development of architectural models and shortening implementation cycles for architectural initiatives.

METHOD

The method used to carry out the study is documentary analysis, which is a technical research method that uses intellectual operations to describe and represent a set of documents, facilitating analysis and retrieval. In general, it corresponds to the qualitative research paradigm where information is collected, compiled and selected from various sources such as documents, journals, books, recordings, among others. In this method, observation is manifested in data analysis, integrating intellectual abilities and skills to support the identification of essential fragments of the documents under study, to arrive at the reconstruction of their content, in a process called "synthesis".

Documentary Analysis aims to represent the content of the documents reviewed for consultation or retrieval, considering the different nuances and important elements. It is not only about scientific-informative extraction as a reflection of the original source, but also about finding new messages and approaches in the analyzed documents. This study is classified as monographic, since it addresses the broad and deep development of enterprise architecture frameworks from a multidimensional approach. The Table 1 provides the specific techniques used within the documentary research.

The following stages were carried out to conduct the study:

1. Search for sources (printed and electronic).
2. Initial reading of available documents.
3. Preparation of the preliminary or tentative outline.
4. Data collection by means of evaluative reading and summary elaboration.
5. Analysis and interpretation of the information collected according to the preliminary outline of the research.
6. Formulation of the final outline and development of the first version of the text.

7. Drafting of the introduction and conclusions.
8. Revision and presentation of the final text.

Table 1.
Methods and techniques used in the study.

Type of analysis	Method or technique	Support	Variants to apply
External formal analysis	Bibliographical description	It acts on the support and identifies the external data of a document that distinguishes it from another, providing an individual identification.	Bibliographic sheets Worksheets (summary)
Internal formal analysis	Content analysis	It operates on the thematic content of the document and achieves a representation of the information processed.	Indexing through descriptors (thesauri)
	Summary or Substantial Description	It refers to the analysis of the contents of documents. It is the abbreviated representation of the contents without critical interpretation.	Mixed summary (informative-selective) Conceptual Map
	Document classification	It is the process of analysis by which a document is identified and sorted by classes, defined according to the content.	Hierarchical classification

Elaboration: The authors.

RESULTS

Frameworks, concepts and importance for enterprise architecture

Undoubtedly, enterprise architecture is very useful in uncertain contexts, as it brings more options for survival, especially the digital era (Aldea & Sarkar, 2022: Ko¸c et al., 2022; Brée& Karger, 2022). Frameworks have developed in parallel with enterprise architecture, as a toolkit that is present in most architectural projects and constitutes a recurring theme in projects of this type. It was Zachman who first published, in *IBM Systems Journal,* an article about a framework entitled: "*A Framework for Information Systems Architecture*" (Chávez & Villar, 2020; Petrov et al., 2022). It was very clear to Zachman that enterprise architecture is a holistic project (Zachman, 1987), as it covers all parts of an enterprise (Afshani et al., 2022).

After the publication of the first version of "*Zachman's Framework*", successive research on the subject focused on understanding architecture frameworks and methodologies, now numbering in the hundreds. Just as there is a wide variety of enterprise architecture concepts, there are several definitions of frameworks, which for the purposes of this research have been grouped into the following categories:

Architecture representation. An enterprise architecture framework is a multidimensional classification scheme, which functions as a conceptual structure. These provide transparency in the unfolding of the complex relationships that manifest between business and architecture artifacts, supporting future scenario planning. By providing a space for generic problem solving, they foster a deliberately abstract and unambiguous conception of the domains that make up the organization. A framework is a useful horizontal component to an architectural practice, capable of aligning different resources, including technology, across the current and future organization. At its inception, the purpose of frameworks was focused on formalizing the modeling of system architecture, but this approach has evolved into a standardized, high-level structure, which is concerned with shaping semantic representations of the entire organization.

A logical description. A framework is considered a logical arrangement, which is made up of a set of artifacts that constitute enterprise-specific descriptions. These may not only include the architecture descriptions, they may also contain standardized methods for producing the artifacts. The logical structure is useful for categorizing and organizing multiple artifacts (Gunadham & Ahmed, 2022), which group a set of concepts, values and practices for viewing reality. Precisely, these artifacts are classified, organized and communicated through the framework, which is the one that defines at a conceptual level the elements or components of the architecture and their relationships.

A standard or model for applying the architecture. A framework can be considered a model for implementing an architecture, since they act as structured processes and

provide a set of support tools and specific guidelines. These models propose a variety of contexts and elements that serve as a basis for developing lines of action or roadmaps. For a framework is a very useful communication tool for documenting architectures. A framework is a set of structures that serve for the development, documentation or modeling of many types of architectures.

An architecture itself. A framework can be used as a tool to develop from an extensive range of different enterprise architectures, or it can also be considered as an architecture. A framework is one of the most deliberately abstract and unambiguous definitions of the elements related to an enterprise, which can define enterprise architecture terminology.

Positive impact of frameworks

Although the benefits of enterprise architecture and its frameworks are sometimes difficult to understand (Hindarto & Putra, 2024b), there is clarity on the important role these frameworks play in describing in detail the logical business functions, along with their capabilities, processes, roles, human actors, physical structures, data flow, applications, platforms, hardware, and communications infrastructure. Frameworks use the necessary data to show the design of the effort, organize data types into consistent structures and delimit the connection between them (Luwi et al., 2021).

Although each framework has its own structure, processes, strategy and models, their importance is irrefutable for enterprise architecture development. For many organizations, both private and public, much of their success in the last 10 years depends on the effective implementation of these models. Many authors agree that part of the success of enterprise architecture is due to the emergence of its frameworks, which has raised expectations about its benefits and increased its popularity (Kotusev, 2021).

Enterprise architecture frameworks are essential for addressing uncertainty and learning (Hindarto & Putra, 2024a), as they optimize processes and facilitate the creation of

scalable and secure platforms (Ningsih et al., 2024). Frameworks can describe specific instances of a reference architecture, developing strict design and implementation rules that can be used to develop multiple architectures (Oberle et al., 2023).

Through a comprehensive review of existing systems and practices, frameworks can restructure and align processes according to industry best practices and standards. They are very useful models for automating routine tasks, reducing manual intervention, and improving the speed and accuracy of operations by enabling automated data entry, standardized report generation, and efficient communication channel management (Hindarto & Putra, 2024a).

Frameworks provide a systematic approach to reorganization projects, which supports specific types of business analysis. This approach has demonstrated its potential to solve the growing needs for process integration in companies characterized by complexity and fragmentation. It has been factually proven that it can be equally useful for large and small companies, due to its strong ability to describe an organization holistically. Frameworks have emerged as a kind of control object, capable of providing the business with an overview of the enterprise and clearly exposing the mutual linkage of its parts into a single whole (Petrov et al., 2022).

The architectural layers presented by frameworks are excellent tools for increasing design consistency and organizational structure. The contribution of frameworks is undeniable, as they contribute to solving the pressure on organizations to survive and adapt to change (Luwi et al., 2021), in the era of digital transformation. The rules and methods for managing the enterprise architecture lifecycle used by frameworks are an important guide for those organizations that want to improve their processes. This is a sign that their role goes beyond modeling to include business planning and control management tasks and the explicit mapping of relationships and dependencies between business services.

A framework identifies the scope of the architecture and establishes relationships between architecture areas, reflecting through a geometric model, creating an abstract set of enterprise views and providing an analytical structure for developing architecture results (Guo et al., 2022a). Furthermore, frameworks are generators of an analytical structure, both for architecture and for its design process. This analytical structure becomes a common basis for professionals who are engaged in the discipline or in some way are users of the discipline (Guo et al., 2022b), bringing capacity to structure organizational thinking and hardware and software working together.

Shortcomings and weaknesses of enterprise architecture frameworks

Considering their practical nature, frameworks have been subject to questioning due to opinions about their individual practices not satisfying all necessary aspects of the enterprise. Strict adherence to frameworks is recognized as one of the worst enterprise architecture practices. According to this author, "frameworks have been suggested as guidelines for enterprise architecture, but our experience indicates that very few companies follow the steps prescribed by such frameworks." For this reason, many of the organizations that apply enterprise architecture initiatives face many problems during implementation projects (Oberle et al., 2023).

Depending on management resources, corporate vision and outcomes, many models have emerged and they emphasize different domains, artifacts and objectives, constituting a wide variety of alternative approaches (Afshani et al., 2022). The large number of existing frameworks has caused these interpretations to vary, considering frameworks as enterprise architectures themselves, meta models of architectures or models where architectures are expressed and conceptualized (Chávez & Villar, 2020).

Considering the diversity of frameworks, it is extremely difficult to know which of the available frameworks could solve the needs of an organization (Chávez, 2023), because of the wide variety of architecture solutions. Their growth, especially in the last decade, is evident and their large number infers a potential difficulty for their practical application

(Guo et al., 2022a). It is sometimes difficult to know before the implementation of a framework whether it will be able to satisfy all the necessary aspects of the enterprise.

Another problem with frameworks is their high level of mutability, so it is common that several of these can be generated from one model, an element that is sometimes not easy to identify in practice (Wedha & Hindarto, 2023). Another aspect to be taken into account in the practical application of frameworks is the resistance to change and the uncertainty surrounding their results. Technical issues, such as complex systems integration and complicated data management, can pose significant impediments during the implementation of enterprise architecture through their frameworks.

Most existing frameworks do not necessarily define the resulting architecture practice, so they still have much room for improvement. Many researchers and experts widely assume that enterprise architecture theory and practice always require the frameworks, which has sparked debate in academia. The role of frameworks can be significantly overstated and could even be an administrative fad. On many occasions, actual architectures practices have no correlation with the frameworks where they have their foundation. Frameworks, although used most enterprise architecture projects, do not seem to fully address alignment with information systems. The viability of enterprise architecture and its frameworks is questionable, especially in large organizations, as many have dimensions with values that do not have a clear relationship to the business practice of the practicing company.

Most of the models proposed by frameworks are not reusable and are designed for a specific purpose. Many enterprise architecture users emphasize the insights that the artifacts could provide, neglecting to focus on how the artifacts should be used to benefit organizations. It is difficult to prioritize the desired qualities of an enterprise architecture model and even more difficult to achieve prioritization in the successful implementation of any model. Sometimes these are not always comprehensive; they can be leveraged

to provide at least an initial set of solutions to problems and concerns that need to be addressed in architecture development.

New trends in thinking about EA frameworks, consider them to have particular theories underlying their technical approach. Many enterprise architecture models start to deliver results in the long term, although some managers desire more immediate results. Finally, other limitations can be mentioned, such as the overestimation of business benefits and the failure to consider individual company characteristics (Petrov et al., 2022).

Updating enterprise architecture frameworks

As discussed in previous sections, the great diversity and variety of frameworks at the international level is a fact that, although it is one of the main problems, has a positive side according to (Chávez, 2023): there are many options and possibilities to successfully carry out enterprise architecture projects without having to start from scratch. Although not always all the frameworks that can be found are not totally original, that is, they are derivations of others that already exist, it should be recognized that there is a wide wealth of approaches, views, artifacts, methods and components. The new list includes 158 frameworks from all regions of the world, both generic and designed for specific sectors (table 2).

Table 2.
Overview of the list of enterprise architecture frameworks.

Type	Quantity	Percentage
Total frameworks	158	100.00%
Generic ones	52	32.91%
Specific sectors	106	67.09%

Elaboration: The authors.

As shown in table 2, frameworks developed for specific industry sectors outnumber generic frameworks by 34.18%, although the proportion of the latter cannot be considered negligible. With more than 30% of the frameworks being generic, enterprise architects or other users of architectural projects have a vast universe in which to choose the solution that best suits their needs. As for the specific sectors, a wide variety of these can be found as shown in Figure 1. Although the number of areas represented in the table above is varied, there is a concentration in several sectors that have been much more favored by the development of frameworks. The Figure 1 presents the concentration of models according to the sectors.

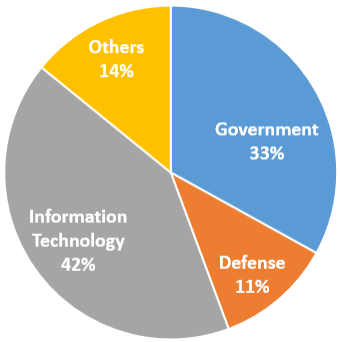

Figure 1. Proportion of frameworks by sector of activity.
Elaboration: The authors.

According to Figure 1, enterprise architecture framework initiatives for the public sector abound internationally (between them they constitute 44% of sector-specific frameworks). The majority of sector-specific frameworks are developed for the IT domain (42%). Among these, the frameworks developed for defense and government management stand out. According to the figure, government frameworks constitute the largest proportion (33%), this sector being one of the first to develop frameworks since the birth of enterprise architecture as a discipline. The public sector has been at the

forefront of the development and application of enterprise architecture frameworks, as one of the most important models has been developed for this sector. This occurs because public organizations have had leadership, at least, in the major economic powers worldwide, in automating their processes and services to society. The Figure 2 illustrates the countries of origin of the frameworks.

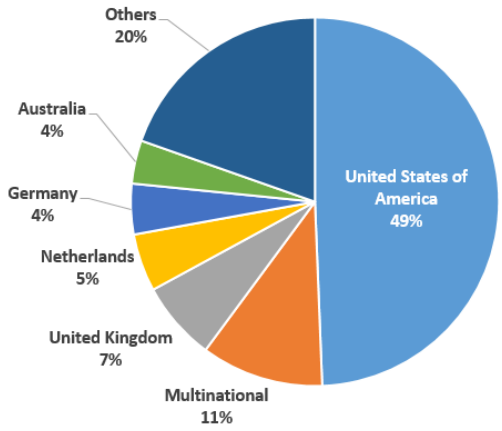

Figure 2. Proportion of frameworks by country of origin.
Elaboration: The authors.

As shown in the figure 2, the United States of America is the nation that has achieved the greatest development not only in the development of frameworks, but also in enterprise architecture. Almost 50% of the frameworks listed have been developed in that nation and many of these frameworks are very relevant at the international level. Twenty-four percent of the frameworks developed in the U.S. are generic, although it is not in this area that they have achieved the greatest notoriety, but in the development of frameworks for government management. A number of 21 frameworks (26%) have been developed for government management at different levels and 10 frameworks (12.82%) have been developed for defense management.

CONCLUSIONS

As with the concept of enterprise architecture, the definition of frameworks is generally ambiguous, although through the four dimensions identified in the research, the most widespread conceptual perspectives in the literature consulted were obtained. Regarding frameworks as a representation of an architecture, they are defined as the standardization of the physical form of an enterprise architecture, through which it is possible to present, apply and improve it. In contrast, for an important group of authors, frameworks are a standard or model for applying the architecture, containing not only a representation, but a group of tools, techniques, models and procedures that are useful for the practical implementation of the architecture.

Taking into account the two approaches of the frameworks agreement in the evolution, development and implementation of enterprise architecture as a discipline, it is clear that although there are limitations to consider, they are highly beneficial. They have not only accompanied enterprise architecture since its inception as a discipline, but have also contributed to the practical application of the theoretical body. Enterprise architecture would never have reached the place it is today without the contributions of frameworks. Other strong points are also relevant, such as its ability to facilitate organizational learning, its ability to facilitate change processes, its usefulness in representing the best practices of many industries and sectors, its ability to provide a comprehensive vision, among other utilities.

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